# ADDENDUM

204620

## Intrinsic Remediation
## Engineering Evaluation/Cost Analysis
## for the FT-002 Site

## Plattsburgh Air Force Base
## New York

Prepared For

## Air Force Center for Environmental Excellence
## Technology Transfer Division
## Brooks Air Force Base
## San Antonio, Texas

## and

## Plattsburgh Air Force Base
## New York

UNITED STATES AIR FORCE
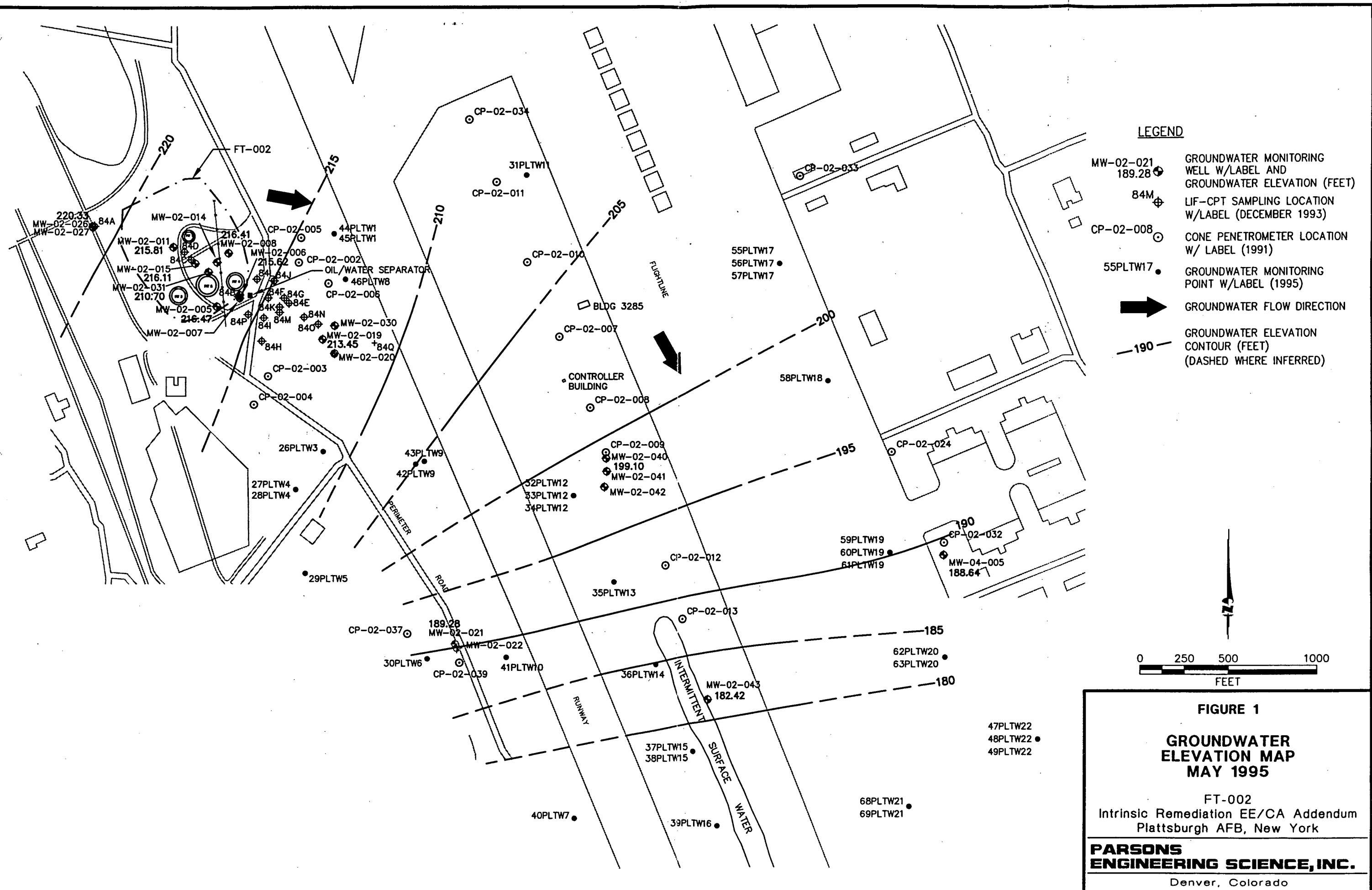1947-1997
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YEARS

March 1997

## 1.0 INTRODUCTION

This report was prepared for the Air Force Center for Environmental Excellence (AFCEE) by Parsons Engineering Science, Inc. (Parsons ES) as an addendum to the Final Intrinsic Remediation Engineering Evaluation/Cost Analysis (EE/CA) for the FT-002 Site, Plattsburgh Air Force Base (AFB), New York (Parsons ES, 1995). The EE/CA was conducted to evaluate the use of intrinsic remediation with long-term monitoring (LTM) for remediation of fuel hydrocarbon contamination dissolved in groundwater at FT-002. In addition, the report provided a qualitative assessment of the natural attenuation of chlorinated ethenes dissolved in site groundwater. This addendum summarizes the results of two subsequent sampling events performed for additional site characterization and as a part of long-term groundwater monitoring at the site. These sampling events were conducted in August 1995 and May 1996 by researchers from the US Environmental Protection Agency (USEPA) National Risk Management Research Laboratory (NRMRL) Subsurface Protection and Remediation Division. The original EE/CA sampling event was conducted in December 1993. The main emphasis of this summary is to evaluate changes in dissolved benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations and extent, chlorinated ethene concentrations and extent, and natural attenuation mechanisms through time at FT-002. A comparison between results, calculations, and predictions presented in the EE/CA and new data provides the basis for this evaluation. In addition, this addendum expands the interpretation and evaluation of natural attenuation of chlorinated solvents.

Site FT-002, formerly designated FT-001, is located in the northwest corner of the base and encompasses an area approximately 700 feet wide and 800 feet long (Figure 1). The FT-002 site is located approximately equidistant (500 feet) between the Plattsburgh AFB runway to the east and the base boundary on the west. The source of contamination at FT-002 is most likely unburned fuel and chlorinated solvents from training exercises that occurred from the mid-1950's to 1989. Additional site information, including site background, geology, and hydrogeology, is provided in the EE/CA (Parsons ES, 1995).

## 2.0 RESULTS

In August 1995, researchers from the USEPA NRMRL collected groundwater samples from 47 new and previously installed monitoring wells/points at FT-002. In May 1996, researchers from the USEPA NRMRL also collected groundwater samples from 24 existing monitoring wells/points at FT-002. During both sampling events, samples were analyzed in the field for dissolved oxygen (DO), temperature, carbon dioxide, alkalinity, pH, conductivity, oxidation/reduction potential (ORP), hydrogen sulfide, and ferrous iron. Additional sample volumes were analyzed at the USEPA NRMRL in Ada, Oklahoma for BTEX, trimethylbenzenes (TMBs), volatile organic compounds (VOCs), nitrate + nitrite, sulfate, methane, and dissolved total organic carbon (TOC). Analytical methods used for these events are summarized in Table 1.

LEGEND

MW-02-021
189.28 ⊕ GROUNDWATER MONITORING WELL W/LABEL AND GROUNDWATER ELEVATION (FEET)

84M ⊕ LIF-CPT SAMPLING LOCATION W/LABEL (DECEMBER 1993)

CP-02-008 ⊙ CONE PENETROMETER LOCATION W/ LABEL (1991)

55PLTW17 • GROUNDWATER MONITORING POINT W/LABEL (1995)

➡ GROUNDWATER FLOW DIRECTION

— 190 — GROUNDWATER ELEVATION CONTOUR (FEET) (DASHED WHERE INFERRED)

FIGURE 1

GROUNDWATER ELEVATION MAP MAY 1995

FT-002
Intrinsic Remediation EE/CA Addendum
Plattsburgh AFB, New York

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## 2.1 Flow Direction and Gradient

In May 1995, groundwater in the vicinity of FT-002 was observed to flow to the southeast (Figure 1), with a gradient that increases from approximately 0.005 foot per foot (ft/ft) in the source area to approximately 0.011 ft/ft in the area of the flightline. The average gradient for the site is approximately 0.009 ft/ft. Towards the flightline the flow direction changes to the south-southeast, along the flightline and towards the intermittent surface water area. The groundwater elevations, gradient, and flow direction measured in May 1995 (Figure 1) are nearly identical to those observed in December 1993 and described in the EE/CA (Parsons ES, 1995). The December 1993 and May 1995 groundwater elevation data are presented in Table 2.

## 2.2 Dissolved BTEX Contamination

BTEX compounds were detected in groundwater samples from 42 of the 47 monitoring wells/points sampled in August 1995. Data collected during the May 1996 sampling event shows that BTEX compounds were detected in 17 of the 24 monitoring wells/points that were sampled. Analytical results for BTEX and TMB samples collected in 1995 and 1996 are summarized in Table 3. Analytical data collected from FT-002 monitoring wells prior to 1995 are summarized in Appendix A. The areal distributions of total dissolved BTEX in August 1995 and May 1996 are presented on Figure 2. In order to illustrate trends in BTEX concentrations and distribution through time, the total BTEX isopleth map derived from December 1993 data is also provided on Figure 2.

Temporal and spatial changes in BTEX concentrations suggest that dissolved BTEX concentrations in the source area are decreasing. This can be observed through the marked decrease in the areal extent of the 1,000- micrograms per liter (µg/L) isopleth between 1993 and 1996, as well as the decreasing concentrations observed at individual monitoring locations. Shrinking of the 1,000-µg/L isopleth over time can be illustrated using groundwater samples from MW-02-019, 900 feet southeast of (downgradient from) MW-108. At this location total BTEX concentrations have decreased from 2,399 µg/L in December 1993 to 1,022 µg/L in August and 979 µg/L in May 1996. In August 1995, the highest total BTEX concentration of 16,790 µg/L was detected in monitoring well MW-108. Well MW-108 is located just southeast of Pit 1, one of the source areas designated for site FT-002 (Parson ES, 1995). In May 1996, the total BTEX concentration detected at well MW-108 (6,596 µg/L) was the highest BTEX concentration detected during the 1996 sampling round and represents a 65 percent decrease from August 1995 (Table 3). MW-108 was not installed at the time of the December 1993 sampling event.

As defined by the August 1995 and May 1996 sampling events, the dissolved BTEX plume emanating from FT-002 is approximately 4,000 feet long (Figure 2). The dissolved BTEX plume extends approximately 1,250 feet further downgradient than estimated for December 1993; however, the plume in December 1993 was not fully defined. Also, given an average contaminant velocity of approximately 57 feet per year (Parsons ES, 1995), the plume potentially could have migrated only 143 feet in the 2.5 years from December 1993

# TABLE 1
## SUMMARY OF GROUNDWATER ANALYTICAL METHODS
### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

| Analyte | Method | Field (F) or Fixed-Base Laboratory (L) |
|---|---|---|
| Ferrous Iron ($Fe^{2+}$) | Colorimetric, Hach Method 8146 | F |
| Oxidation\Reduction Potential | Direct Reading Meter | F |
| Dissolved Oxygen | Direct Reading Meter | F |
| pH | Direct Reading Meter | F |
| Conductivity | Direct Reading Meter | F |
| Temperature | Direct Reading Meter | F |
| Carbon Dioxide | Titrimetric, Hach Method 1436-01 | F |
| Alkalinity (Carbonate [$CO_3^{2-}$] and Biocarbonate [$HCO_3^-$]) | Titrimetric, Hach Method 8221 | F |
| Nitrate + Nitrite | EPA Method 353.1 | L |
| Sulfate | Waters Capillary Electrophoresis Method N-601 | L |
| Methane, Ethane and Ethene | RSKSOP-175[a] and RSKSOP-147 | L |
| Dissolved Organic Carbon | RSKSOP-102 | L |
| BTEX and TMBs | RSKSOP-133 | L |
| Chlorinated VOCs | RSKSOP-148 | L |

[a] RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

**TABLE 2**
**GROUNDWATER ELEVATION DATA**
**FT-002**
**Intrinsic Remediation EE/CA Addendum**
**Plattsburgh AFB, New York**

| Location | Easting | Northing | Date | Datum Elevation (ft msl)[a] | Groundwater Elevation (ft msl) |
|---|---|---|---|---|---|
| MW-02-005 | 722393.85 | 1700306.02 | 12/93 | 250.92 | NA[b] |
| MW-02-005 | 722393.85 | 1700306.02 | 5/95 | 250.92 | 216.47 |
| MW-02-006 | 722521.64 | 1700372.17 | 12/93 | 245.80 | NA |
| MW-02-006 | 722521.64 | 1700372.17 | 5/95 | 245.80 | 215.62 |
| MW-02-007 | 722521.41 | 1700354.16 | 12/93 | 248.69 | 216.29 |
| MW-02-008 | NA | NA | 5/95 | 257.40 | 216.41 |
| MW-02-011 | NA | NA | 5/95 | 258.32 | 215.81 |
| MW-02-014 | 722146.23 | 1700554.89 | 12/93 | 254.01 | NA |
| MW-02-015 | 722023.54 | 1700547.37 | 12/93 | 256.25 | 216.22 |
| MW-02-015 | 722023.54 | 1700547.37 | 5/95 | 256.25 | 216.11 |
| MW-02-019 | 722797.86 | 1700166.45 | 12/93 | 227.93 | 213.08 |
| MW-02-019 | 722797.86 | 1700166.45 | 5/95 | 227.93 | 213.45 |
| MW-02-020 | 722807.69 | 1700165.37 | 12/93 | 230.16 | 217.01 |
| MW-02-021 | 723492.61 | 1698394.41 | 12/93 | 193.85 | 189.86 |
| MW-02-021 | 723492.61 | 1698394.41 | 5/95 | 193.85 | 189.28 |
| MW-02-026 | 721429.01 | 1700757.23 | 12/93 | 274.06 | 217.66 |
| MW-02-026 | 721429.01 | 1700757.23 | 5/95 | 274.06 | 220.33 |
| MW-02-027 | 721430.77 | 1700751.15 | 12/93 | 274.22 | 221.17 |
| MW-02-030 | 722808.70 | 1700172.70 | 12/93 | 229.55 | 214.95 |
| MW-02-031 | 722098.87 | 1700498.83 | 12/93 | 250.81 | 216.93 |
| MW-02-031 | 722098.87 | 1700498.83 | 5/95 | 250.81 | 216.70 |
| MW-02-040 | 724351.63 | 1699361.02 | 12/93 | 209.02 | 199.62 |
| MW-02-040 | 724351.63 | 1699361.02 | 5/95 | 209.02 | 199.10 |
| MW-02-041 | 724363.83 | 1699363.58 | 12/93 | 209.05 | 200.72 |
| MW-02-042 | 724368.43 | 1699352.83 | 12/93 | 208.76 | 200.86 |
| MW-02-043 | 724953.42 | 1698070.12 | 12/93 | 185.47 | 182.02 |
| MW-02-044 | 725474.64 | 1697178.35 | 12/93 | 190.21 | 182.59 |
| MW-04-005 | NA | NA | 5/95 | 190.96 | 188.64 |
| 84B | 722267.00 | 1700360.00 | 12/93 | 241.52 | 216.02 |
| 84E | 722437.00 | 1700360.00 | 12/93 | 241.52 | 213.52 |
| 84F | 722437.00 | 1700360.00 | 12/93 | 244.26 | 215.76 |
| 84M | 722502.00 | 1700270.00 | 12/93 | 243.40 | 214.40 |
| 84O | 722723.00 | 1700310.00 | 12/93 | 234.10 | 212.50 |

[a] ft msl = feet above mean sea level.

[b] NA = data not available.

# TABLE 3
## GROUNDWATER QUALITY DATA FOR FUEL HYDROCARBONS
### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

| Sample Location | Sample Date | Benzene (µg/L)[a] | Toluene (µg/L) | Ethylbenzene (µg/L) | Total Xylenes (µg/L) | Total BTEX (µg/L) | 1,3,5-TMB[b] (µg/L) | 1,2,4-TMB[c] (µg/L) | 1,2,3-TMB[d] (µg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 25-PLT-W2 | 8/95 | ND[e] | ND | ND | ND | ND | ND | ND | ND |
| 26-PLT-W3 | 8/95 | ND | ND | ND | ND | ND | ND | ND | ND |
| 27-PLT-W4 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | < 1.0 | ND | 0.9 |
| 28-PLT-W4 | 8/95 | ND | < 1.0 | ND | <1.0 | <2.0 | ND | ND | ND |
| 29-PLT-W5 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 30-PLT-W6 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 31-PLT-W11 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 32-PLT-W12 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 33-PLT-W12 | 8/95 | 12 | < 1.0 | ND | 1.7 | 13.7 | 1.2 | ND | ND |
| 34-PLT-W12 | 8/95 | 39.9 | < 1.0 | ND | ND | 39.9 | ND | ND | ND |
| 35-PLT-W13 | 8/95 | 2.2 | ND | ND | ND | 2.2 | < 1.0 | ND | ND |
| 36-PLT-W14 | 8/95 | 2.5 | < 1.0 | ND | ND | 2.5 | ND | ND | ND |
| 37-PLT-W15 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 38-PLT-W15 | 8/95 | < 1.0 | < 1.0 | ND | ND | <2.0 | ND | ND | ND |
| 39-PLT-W16 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 40-PLT-W7 | 8/95 | ND | 0.9 | ND | ND | 0.9 | ND | ND | ND |
| 41-PLT-W10 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | 0.9 | 0.9 | < 1.0 |
| 42-PLT-W9 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 43-PLT-W9 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 44-PLT-W1 | 8/95 | ND | ND | ND | ND | ND | ND | ND | ND |
| 45-PLT-W1 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 46-PLT-W8 | 8/95 | 129 | 34 | 62.3 | 37.1 | 262.4 | 6.7 | 2.8 | 13.2 |
| 47-PLT-W22 | 8/95 | ND | 2.4 | < 1.0 | 1.5 | 3.9 | ND | ND | ND |
| 49-PLT-W22 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 55-PLT-W17 | 8/95 | < 1.0 | 1.3 | ND | ND | 1.3 | ND | ND | ND |
| 56-PLT-W17 | 8/95 | ND | < 1.0 | ND | <1.0 | <2.0 | ND | ND | ND |
| 57-PLT-W17 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 58-PLT-W18 | 8/95 | ND | 1.9 | ND | 1.0 | 2.9 | ND | ND | ND |
| 59-PLT-W19 | 8/95 | ND | 1.0 | ND | ND | 1.0 | ND | ND | ND |
| 60-PLT-W19 | 8/95 | ND | ND | ND | ND | ND | ND | ND | ND |
| 61-PLT-W19 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | < 1.0 | ND | ND |
| 63-PLT-W20 | 8/95 | ND | ND | ND | ND | ND | < 1.0 | ND | ND |
| 68-PLT-W21 | 8/95 | ND | 3.6 | ND | ND | 3.6 | ND | ND | ND |
| 69-PLT-W21 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| 84-DA | 8/95 | 333 | 380 | 526 | 1589 | 2828.0 | 96.9 | 203 | 104 |
| 84-DB | 8/95 | 619 | 1640 | 1060 | 4035 | 7354.0 | 193 | 465 | 228 |
| 84-DC | 8/95 | 10.6 | 11.3 | 14.4 | 18.6 | 54.9 | 1.4 | 2.4 | 2.3 |
| 84-DD | 8/95 | 435 | 793 | 646 | 1669 | 3543.0 | 123 | 243 | 122 |
| MW-108 | 8/95 | 1900 | 6620 | 1540 | 6730 | 16790.0 | 323 | 949 | 485 |

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# TABLE 3 (concluded)
## GROUNDWATER QUALITY DATA FOR FUEL HYDROCARBONS
### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

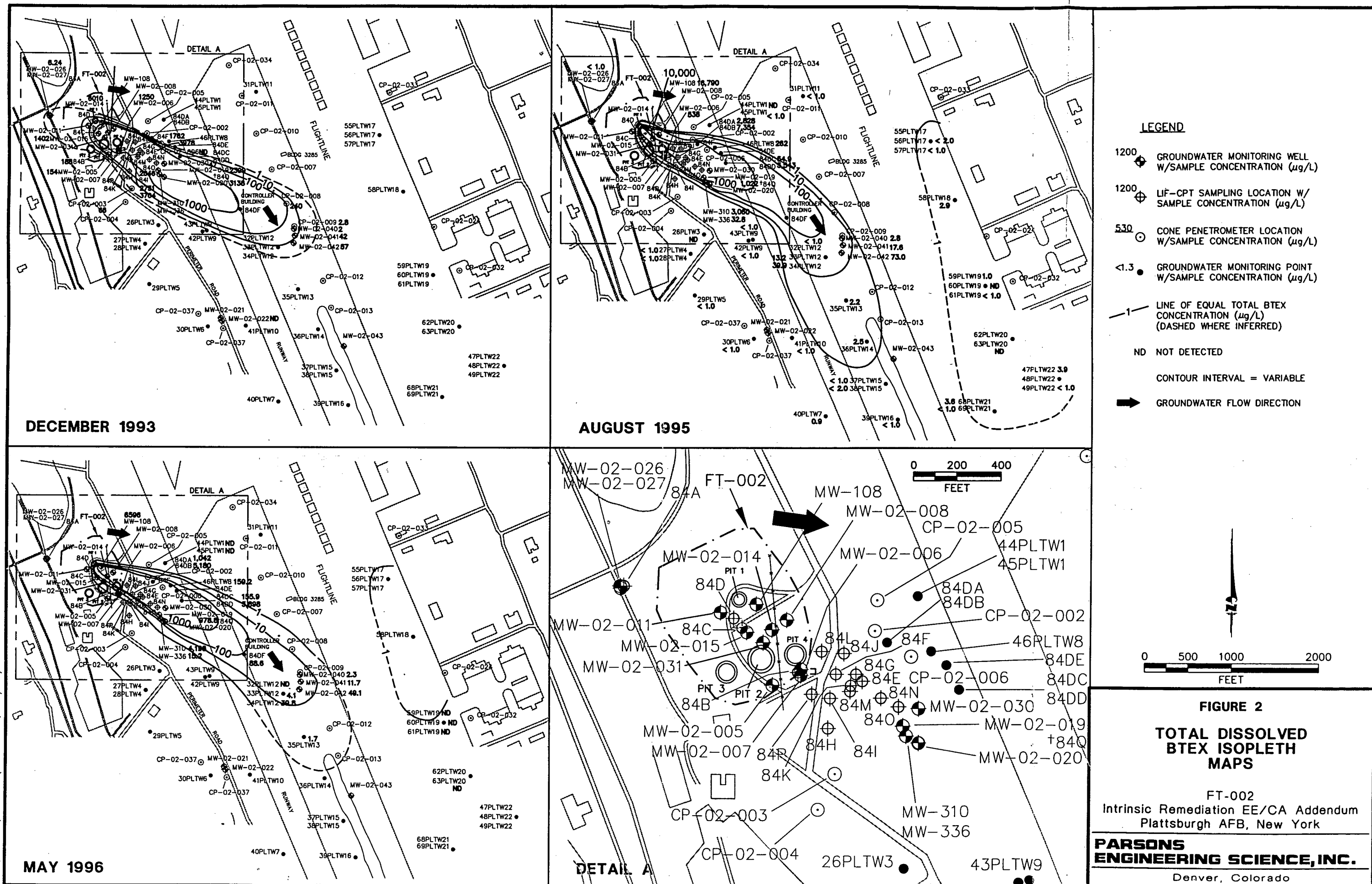| Sample Location | Sample Date | Benzene (µg/L)[a] | Toluene (µg/L) | Ethylbenzene (µg/L) | Total Xylenes (µg/L) | Total BTEX (µg/L) | 1,3,5-TMB[b] (µg/L) | 1,2,4-TMB[c] (µg/L) | 1,2,3-TMB[d] (µg/L) |
|---|---|---|---|---|---|---|---|---|---|
| MW-02-006 | 8/95 | 2.7 | 35 | 179 | 321 | 537.9 | 38.6 | 101 | 50.3 |
| MW-02-019 | 8/95 | 148 | 109 | 338 | 427 | 1022.0 | 45 | 111 | 66.3 |
| MW-02-026 | 8/95 | ND | < 1.0 | ND | ND | <1.0 | ND | ND | ND |
| MW-02-040 | 8/95 | 2.8 | ND | ND | ND | 2.8 | < 1.0 | ND | ND |
| MW-02-041 | 8/95 | 17.6 | < 1.0 | ND | ND | 17.6 | < 1.0 | ND | < 1.0 |
| MW-02-042 | 8/95 | 72 | < 1.0 | ND | 1.0 | 73.0 | < 1.0 | < 1.0 | ND |
| MW-310 | 8/95 | 424 | 678 | 445 | 1513 | 3060.0 | 116 | 248 | 127 |
| MW-336 | 8/95 | 20.3 | < 1.0 | 12.5 | ND | 32.8 | ND | ND | ND |
| MW-02-019 | 5/96 | 115 | 107 | 303 | 453.8 | 978.8 | 39.8 | 111 | 62.2 |
| MW-02-040 | 5/96 | 2.3 | ND | ND | ND | 2.3 | ND | 1.4 | ND |
| MW-02-041 | 5/96 | 11.7 | ND | ND | ND | 11.7 | ND | ND | ND |
| MW-02-042 | 5/96 | 49.1 | ND | ND | ND | 49.1 | ND | ND | ND |
| 32-PLT-W12 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 33-PLT-W12 | 5/96 | 3.0 | ND | ND | 1.1 | 4.1 | ND | ND | ND |
| 34-PLT-W12 | 5/96 | 39.8 | < 1.0 | ND | ND | 39.8 | ND | ND | ND |
| 35-PLT-W13 | 5/96 | 1.7 | ND | ND | ND | 1.7 | ND | ND | ND |
| 44-PLT-W1 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 45-PLT-W1 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 46-PLT-W8 | 5/96 | 98.8 | 7.5 | 48.8 | 4.3 | 159.4 | 2.9 | ND | 11.4 |
| 59-PLT-W19 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 60-PLT-W19 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 61-PLT-W19 | 5/96 | ND | ND | ND | ND | ND | ND | ND | ND |
| 63-PLT-W20 | 5/96 | ND | ND | ND | ND | ND | 1.2 | ND | ND |
| 84DA | 5/96 | 161 | 126 | 326 | 429.1 | 1042.1 | 43.2 | 123.3 | 67.4 |
| 84DB | 5/96 | 456 | 1390 | 705 | 2629 | 5180.0 | 82.2 | 264 | 133 |
| 84DC | 5/96 | 39.2 | 22.2 | 64.1 | 30.4 | 155.9 | ND | 6.0 | 14.3 |
| 84DD | 5/96 | 489 | 845 | 608 | 1956 | 3898.0 | 99.9 | 280 | 129 |
| 84DF-22 | 5/96 | 2.8 | < 1.0 | ND | 3.6 | 6.4 | ND | 1.4 | ND |
| 84DF-34 | 5/96 | 67.5 | 14.6 | 1.1 | 5.4 | 88.6 | 2.0 | ND | 6.7 |
| MW-310 | 5/96 | 512 | 1200 | 564 | 1922 | 4198.0 | 89 | 254 | 120 |
| MW-336 | 5/96 | 9.2 | < 1.0 | 6.0 | ND | 15.2 | ND | ND | ND |
| MW-108 | 5/96 | 261 | 1660 | 896 | 3779 | 6596.0 | 132 | 472 | 224 |

[a] µg/L = micrograms per liter.
[b] 1,3,5 TMB = 1,3,5 trimethylbenzene.
[c] 1,2,4 TMB = 1,2,4 trimethylbenzene.
[d] 1,2,3 TMB = 1,2,3 trimethylbenzene.
[e] ND = not detected.

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DECEMBER 1993

AUGUST 1995

MAY 1996

DETAIL A

LEGEND

1200 ⊕ GROUNDWATER MONITORING WELL W/SAMPLE CONCENTRATION (μg/L)

1200 ⊕ LIF-CPT SAMPLING LOCATION W/ SAMPLE CONCENTRATION (μg/L)

530 ⊙ CONE PENETROMETER LOCATION W/SAMPLE CONCENTRATION (μg/L)

<1.3 • GROUNDWATER MONITORING POINT W/SAMPLE CONCENTRATION (μg/L)

—1— LINE OF EQUAL TOTAL BTEX CONCENTRATION (μg/L) (DASHED WHERE INFERRED)

ND NOT DETECTED

CONTOUR INTERVAL = VARIABLE

➤ GROUNDWATER FLOW DIRECTION

0    200    400
FEET

0    500    1000    2000
FEET

FIGURE 2

TOTAL DISSOLVED BTEX ISOPLETH MAPS

FT-002
Intrinsic Remediation EE/CA Addendum
Plattsburgh AFB, New York

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ENGINEERING SCIENCE, INC.

Denver, Colorado

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to May 1996, if biodegradation were not occurring. Therefore, the apparent expansion of the dissolved BTEX plume between 1993 and 1995 can be attributed to the downgradient extension of the groundwater monitoring network; more downgradient monitoring locations were sampled in August 1995 and May 1996 than were sampled in December 1993.

Comparisons between the extent of the observed dissolved BTEX plume in August 1995 and May 1996 and model predictions presented in the EE/CA are inappropriate because predictions were based on a BTEX plume calibrated to the estimated extent of the December 1993 dissolved BTEX plume. As discussed in the above paragraphs, the leading edge of the December 1993 BTEX plume likely extended at least 1,200 feet further downgradient than estimated. Therefore, model predictions of plume migration are inaccurate, because the leading edge of the plume was not sufficiently characterized in December 1993. However, the observed decreases in dissolved BTEX concentrations in the source area are consistent with model predictions made in Section 6 of the FT-002 EE/CA.

A second area of dissolved BTEX contamination was identified during the August 1995 sampling round. Groundwater samples from monitoring points 47PLTW22 through 69PLTW21, located on the east side of the flightline and directly across from FT-002, had total BTEX concentrations ranging from less than 1.0 µg/L to 3.9 µg/L. Although the sampling program in May 1996 did not allow for confirmation of this observation, analytical results from the ramp survey (OHM, 1996) presented in Appendix A confirm that an unknown source of both dissolved BTEX and chlorinated solvent contamination exists on the east side of the flightline.

## 2.3 Dissolved Chlorinated Solvent Contamination

The areal extents of total dissolved chlorinated solvents detected in groundwater for December 1993, August 1995 and May 1996 are presented on Figure 3. Perchloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (DCE), *trans*-1,2-DCE, and vinyl chloride were detected during each of the three sampling events. The concentrations of individual chlorinated solvent compounds, ethene, and ethane for the August 1995 and May 1996 sampling events are presented in Table 4. Dissolved chlorinated solvent data collected at FT-002 prior to 1995 are presented in Appendix A. In August 1995 and May 1996, the chlorinated solvent plume was approximately 5,500 feet long and 2,750 feet wide, as defined by the estimated extent of the 1-µg/L isopleth, with the highest dissolved chlorinated aliphatic hydrocarbon (CAH) concentrations coinciding with the highest dissolved BTEX concentrations in the source area. During both sampling events, the maximum observed total chlorinated solvent concentration was detected in the sample collected from MW-108. The May 1996 total CAH concentration of 13,165 µg/L represents an 80 percent decrease in the total chlorinated solvent contamination from August 1995, when the total concentrations of chlorinated solvents exceeded 75,000 µg/L. Monitoring well MW-108 was not installed at the time of the 1993 sampling event; however, August 1995 and May 1996 groundwater samples taken from MW-02-041 and MW-02-042, approximately 2,500 feet downgradient from MW-108, showed a slight, though steady, decrease in total dissolved chlorinated solvent concentrations since the December 1993 sampling event.

# TABLE 4
## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND DAUGHTER PRODUCTS
### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

| Sample Location | Sample Date | Vinyl Chloride (µg/L)[a] | trans-DCE[b] (µg/L) | cis-DCE[c] (µg/L) | TCE[d] (µg/L) | PCE[e] (µg/L) | Total Chlorinated Solvents (µg/L) | Ethene (µg/L) |
|---|---|---|---|---|---|---|---|---|
| 25-PLT-W2 | 8/95 | ND[f] | ND | ND | ND | ND | ND | ND |
| 26-PLT-W3 | 8/95 | ND | ND | ND | 1.2 | ND | 1.2 | ND |
| 27-PLT-W4 | 8/95 | 1.2 | ND | < 1.0 | ND | ND | 1.2 | ND |
| 28-PLT-W4 | 8/95 | ND | ND | ND | 1.0 | ND | 1.0 | ND |
| 29-PLT-W5 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 30-PLT-W6 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 31-PLT-W11 | 8/95 | 12.6 | ND | 2.3 | < 1.0 | ND | 14.9 | ND |
| 32-PLT-W12 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 33-PLT-W12 | 8/95 | 246 | ND | 141 | < 1.0 | ND | 387.0 | 0.007 |
| 34-PLT-W12 | 8/95 | 8.3 | 5.4 | 2210 | 24 | ND | 2247.7 | <0.003 |
| 35-PLT-W13 | 8/95 | 4.9 | ND | 226 | 1.1 | ND | 232.0 | <0.003 |
| 36-PLT-W14 | 8/95 | 1.0 | 1.0 | 115 | 1.2 | ND | 118.2 | ND |
| 37-PLT-W15 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 38-PLT-W15 | 8/95 | 1.6 | ND | 24.5 | ND | ND | 26.1 | ND |
| 39-PLT-W16 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 40-PLT-W7 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 41-PLT-W10 | 8/95 | ND | ND | < 1.0 | ND | ND | <1.0 | ND |
| 42-PLT-W9 | 8/95 | ND | ND | 7.9 | 1.2 | ND | 9.1 | ND |
| 43-PLT-W9 | 8/95 | ND | ND | 6.8 | 1.0 | ND | 7.8 | ND |
| 44-PLT-W1 | 8/95 | ND | ND | 2.9 | 302 | 2.4 | 307.3 | ND |
| 45-PLT-W1 | 8/95 | ND | ND | < 1.0 | 6.8 | ND | 6.8 | ND |
| 46-PLT-W8 | 8/95 | ND | 2.7 | 3990 | 279 | 2.8 | 4274.5 | <0.003 |
| 47-PLT-W22 | 8/95 | ND | ND | ND | 2.6 | ND | 2.6 | ND |
| 49-PLT-W22 | 8/95 | ND | ND | ND | 3.5 | ND | 3.5 | ND |
| 55-PLT-W17 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 56-PLT-W17 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| 57-PLT-W17 | 8/95 | ND | ND | ND | 1.0 | ND | 1.0 | ND |
| 58-PLT-W18 | 8/95 | ND | ND | ND | 12 | ND | 12.0 | ND |
| 59-PLT-W19 | 8/95 | ND | ND | ND | ND | ND | ND | <0.003 |
| 60-PLT-W19 | 8/95 | ND | ND | ND | < 1.0 | ND | <1.0 | ND |
| 61-PLT-W19 | 8/95 | ND | ND | 6.7 | 354 | < 1.0 | 360.7 | ND |
| 63-PLT-W20 | 8/95 | ND | < 1.0 | 23.2 | 674 | 1.2 | 698.4 | ND |
| 68-PLT-W21 | 8/95 | ND | ND | 11.6 | < 1.0 | ND | 11.6 | NA[g] |
| 69-PLT-W21 | 8/95 | ND | ND | 1.6 | 1.3 | ND | 2.9 | ND |
| 84-DA | 8/95 | 946 | 6.7 | 2450 | 1.3 | ND | 3404.0 | 0.028 |
| 84-DB | 8/95 | 788 | ND | 1800 | < 1.0 | ND | 2588.0 | 0.208 |
| 84-DC | 8/95 | 122 | ND | 94.6 | 9.5 | ND | 226.1 | 0.017 |
| 84-DD | 8/95 | 1430 | 16.5 | 10000 | 2.95 | ND | 11449.5 | 0.182 |
| MW-108 | 8/95 | 10 | ND | 51360 | 27200 | ND | 78570.0 | <0.003 |
| MW-02-006 | 8/95 | ND | ND | 23 | < 1.0 | ND | 23.0 | ND |

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TABLE 4 (concluded)

# GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND DAUGHTER PRODUCTS

## FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Vinyl Chloride (μg/L)[a/] | trans-DCE[b/] (μg/L) | cis-DCE[c/] (μg/L) | TCE[d/] (μg/L) | PCE[e/] (μg/L) | Total Chlorinated Solvents (μg/L) | Ethene (μg/L) |
|---|---|---|---|---|---|---|---|---|
| MW-02-019 | 8/95 | 414 | ND | 157 | < 1.0 | ND | 571.0 | 0.649 |
| MW-02-026 | 8/95 | ND | ND | ND | ND | ND | ND | ND |
| MW-02-040 | 8/95 | 2.3 | ND | 697 | 3.4 | < 1.0 | 702.7 | <0.003 |
| MW-02-041 | 8/95 | ND | 2.3 | 3950 | 15.3 | ND | 3967.6 | <0.003 |
| MW-02-042 | 8/95 | 2.7 | 1.2 | 1550 | 61.2 | ND | 1615.1 | 0.004 |
| MW-310 | 8/95 | 897 | 13.5 | 14930 | 2.2 | ND | 15842.7 | 0.035 |
| MW-336 | 8/95 | ND | < 1.0 | 158 | 77.1 | ND | 235.1 | ND |
| PTAN SEWER | 8/95 | ND | ND | 2.4 | 41.3 | ND | 43.7 | NA |
| MW-02-019 | 5/96 | 782 | 1.2 | 63.6 | 6.7 | < 1.0 | 853.5 | 0.420 |
| MW-02-040 | 5/96 | 2.1 | ND | 543 | 2.3 | ND | 547.4 | <0.003 |
| MW-02-041 | 5/96 | ND | 1.3 | 2618 | 5.6 | ND | 2624.9 | <0.003 |
| MW-02-042 | 5/96 | 3.8 | < 1.0 | 1043 | 21.1 | ND | 1067.9 | 0.003 |
| 32-PLT-W12 | 5/96 | ND | ND | 2.8 | ND | ND | 2.8 | ND |
| 33-PLT-W12 | 5/96 | 21.8 | ND | 90.3 | ND | ND | 112.1 | <0.003 |
| 34-PLT-W12 | 5/96 | 12.1 | 6.1 | 1880 | 17.4 | ND | 1915.6 | <0.003 |
| 35-PLT-W13 | 5/96 | 3.7 | < 1.0 | 177 | < 1.0 | ND | 180.7 | NA |
| 44-PLT-W1 | 5/96 | ND | ND | 1.3 | 130 | 1.8 | 133.1 | ND |
| 45-PLT-W1 | 5/96 | ND | ND | ND | 5.0 | ND | 5.0 | ND |
| 46-PLT-W8 | 5/96 | ND | 3.4 | 4506 | 118 | 1.5 | 4628.9 | NA |
| 59-PLT-W19 | 5/96 | ND | ND | < 1.0 | 6.6 | ND | 6.6 | <0.003 |
| 60-PLT-W19 | 5/96 | ND | ND | ND | 2.1 | ND | 2.1 | ND |
| 61-PLT-W19 | 5/96 | ND | ND | 4.2 | 206 | ND | 210.2 | ND |
| 63-PLT-W20 | 5/96 | ND | ND | 24.8 | 700 | 1.1 | 725.9 | ND |
| 84DA | 5/96 | 387 | ND | 169 | < 1.0 | ND | 556.0 | 0.257 |
| 84DB | 5/96 | 1885 | 7.3 | 2828 | < 1.0 | ND | 4720.3 | 0.713 |
| 84DC | 5/96 | 146 | ND | 74.4 | 4.8 | ND | 225.2 | 0.089 |
| 84DD | 5/96 | 940 | 9.0 | 10300 | 1.4 | ND | 11250.4 | 0.170 |
| 84DF-22 | 5/96 | 91.6 | ND | 51.4 | ND | ND | 143.0 | 0.004 |
| 84DF-34 | 5/96 | 524 | 1.1 | 1420 | ND | ND | 1945.1 | 0.004 |
| MW-310 | 5/96 | 1520 | 7.8 | 9350 | 1.3 | ND | 10879.1 | 0.141 |
| MW-336 | 5/96 | 1.2 | < 1.0 | 136 | 54 | ND | 191.2 | <0.003 |
| MW-108 | 5/96 | ND | 2.3 | 12600 | 562 | < 1.0 | 13164.3 | <0.003 |

[a/] μg/L = micrograms per liter.
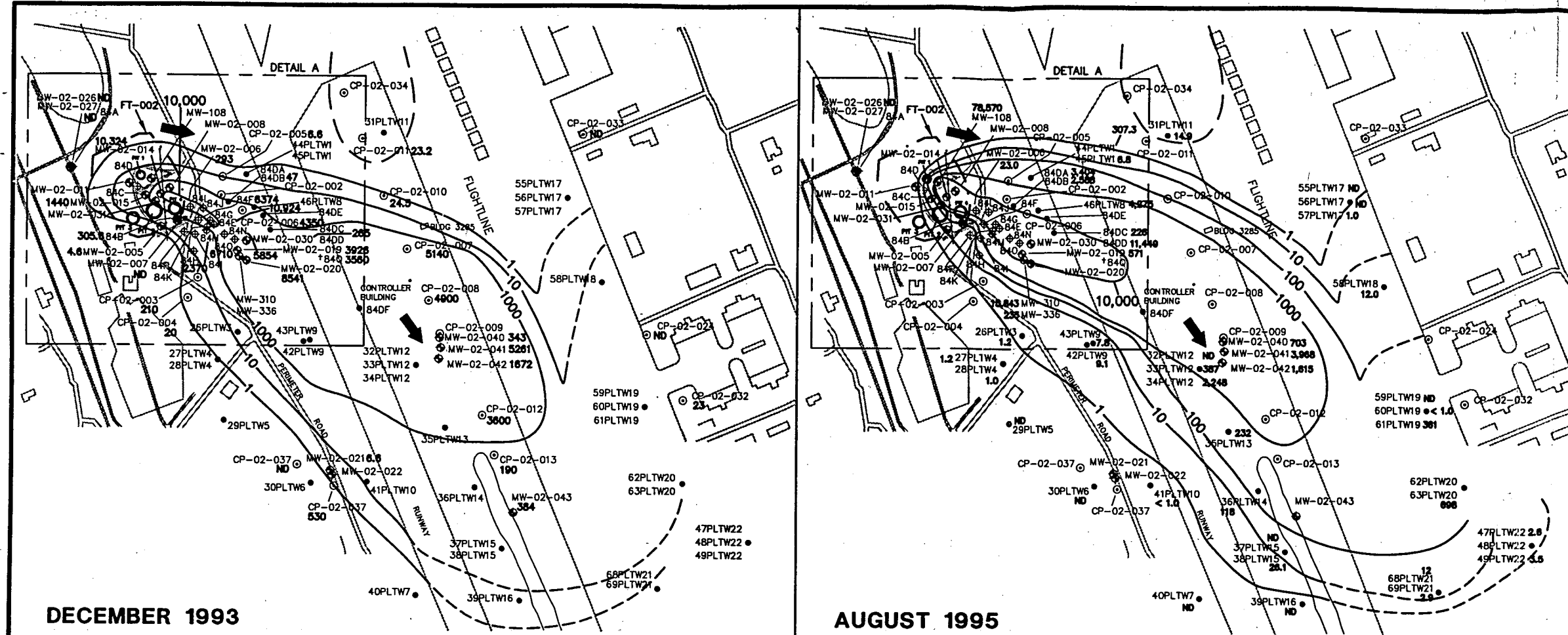[b/] trans-DCE = trans-1,2-dichloroethlene.
[c/] cis-DCE = cis-1,2-dichloroethlene.
[d/] TCE = trichloroethlene.
[e/] PCE = tetrachloroethlene.
[f/] ND = not detected.
[g/] NA = data not available.

DECEMBER 1993

AUGUST 1995

MAY 1996

DETAIL A

LEGEND

1200 ◈ GROUNDWATER MONITORING WELL W/SAMPLE CONCENTRATION (µg/L)

1200 ⊙ LIF-CPT SAMPLING LOCATION W/ SAMPLE CONCENTRATION (µg/L)

530 ⊙ CONE PENETROMETER LOCATION W/SAMPLE CONCENTRATION (µg/L)

ND ● GROUNDWATER MONITORING POINT W/SAMPLE CONCENTRATION (µg/L)

—1— LINE OF EQUAL TOTAL CHLORINATED SOLVENTS CONCENTRATION (µg/L) (DASHED WHERE INFERRED)

ND NOT DETECTED

CONTOUR INTERVAL = VARIABLE

➤ GROUNDWATER FLOW DIRECTION

0   200   400
FEET

0   500   1000   2000
FEET
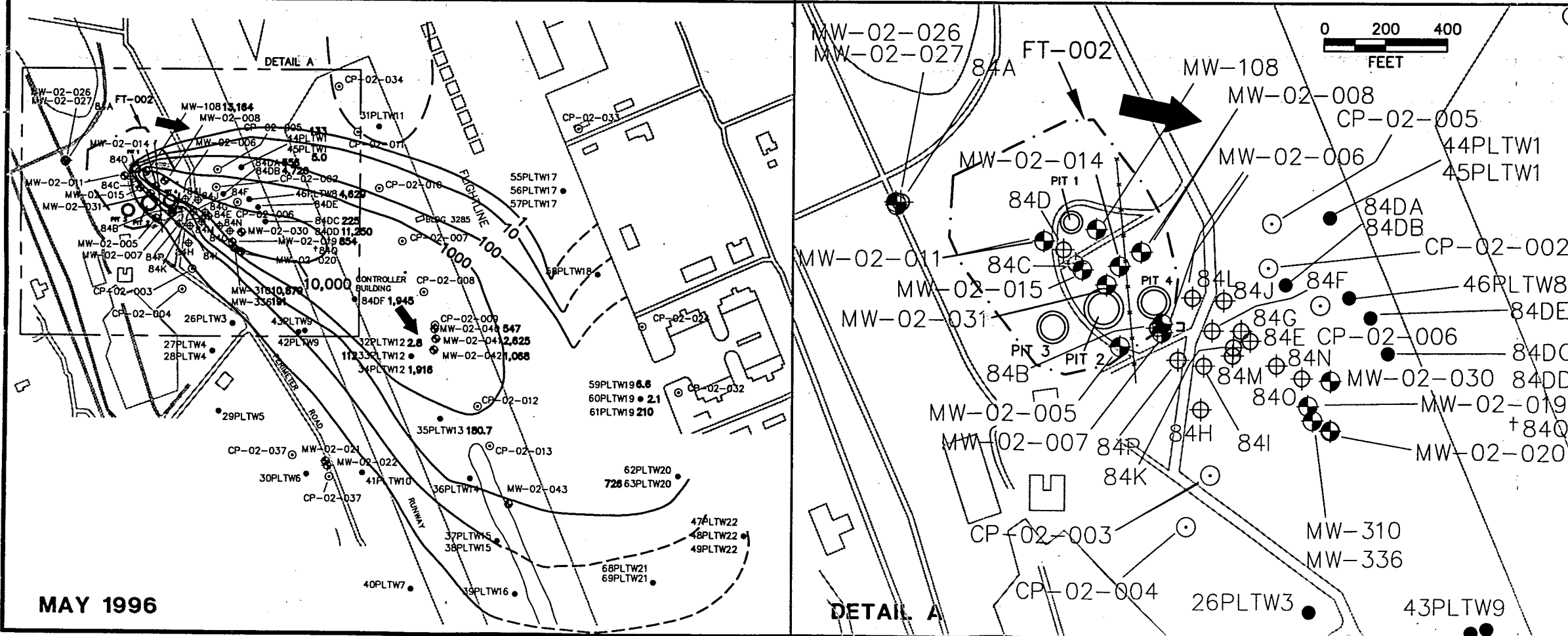
**FIGURE 3**

**TOTAL DISSOLVED CHLORINATED SOLVENTS ISOPLETH MAPS**

FT-002
Intrinsic Remediation EE/CA Addendum
Plattsburgh AFB, New York

**PARSONS ENGINEERING SCIENCE, INC.**

Denver, Colorado

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The CAH *cis*-1,2-DCE was detected at the highest concentrations and at most locations during all three sampling events. In December 1993, approximately 86 percent of detected dissolved CAH mass was *cis*-1,2-DCE; 9 percent was vinyl chloride, 4 percent was TCE, and less than 1 percent was PCE and *trans*-1,2-DCE combined. In August 1995, approximately 87 percent (74 percent including MW-108) of detected dissolved CAH mass was *cis*-1,2-DCE; 10 percent (4 percent including MW-108) was vinyl chloride, 3 percent (22 percent including MW-108) was TCE, and less than 1 percent was PCE and *trans*-1,2-DCE, combined. Both the magnitude and composition of the detected chlorinated solvent concentrations in the MW-108 sample from August 1995 may reflect an emulsification of product with the groundwater during sampling. Alternatively, both the higher chlorinated solvent concentrations as well as the higher ratio of TCE to other chlorinated compounds in MW-108 in August 1995 could suggest that a slug of less-degraded chlorinated solvent contamination entered the system. In either case, in May 1996, chlorinated solvent concentrations and ratios at MW-108 are similar to the rest of the site. In May 1996, approximately 86 percent of detected dissolved CAH mass was *cis*-1,2-DCE; 10 percent was vinyl chloride, 3 percent was TCE, and less than 1 percent was PCE and *trans*-1,2-DCE, combined. The similarity of the average chlorinated solvent ratios from 1993 to 1996 suggest that the chlorinated solvent plume is at steady state, and that degradation rates for the individual chlorinated compounds have remained steady through time.

There has been no apparent change in the areal extent of the total dissolved chlorinated solvent plume during the three sampling rounds between 1993 and 1996; however, the downgradient extent was not defined to below 100 µg/L during either the December 1993 or May 1996 sampling events. Furthermore, a concentration of approximately 3 µg/L was detected in the furthest downgradient well sampled in August 1995 (49PLTW22). Downgradient from the FT-002 source area, the chlorinated solvent plume appears to be joined by a second plume originating from an unknown source on the east side of the flightline. The May 1996 sampling event and the ramp survey (OHM, 1996) confirm that an alternate source of dissolved chlorinated solvent contamination, unrelated to FT-002, exists on the east side of the flightline in the area characterized by monitoring well/points 47PLTW22 through 69PLTW21. The ramp survey (OHM, 1996) also suggests that chlorinated solvent contamination extends further downgradient along the flightline, beyond the area of study addressed in this addendum. Analytical results from the ramp survey can be found in Appendix A.

## 2.4 Biodegradation of BTEX

As discussed in the EE/CA, microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous oxidation/reduction reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at FT-002 include natural organic carbon, fuel hydrocarbon compounds, and the less chlorinated ethenes (DCE and vinyl chloride). Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992). Electron acceptors are elements or compounds that occur in relatively oxidized states. Native electron acceptors include oxygen, nitrate, ferric iron, sulfate, and carbon dioxide. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). Dissolved oxygen is

utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, ferric iron, sulfate, and finally carbon dioxide. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron, and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990). Under certain conditions, chlorinated ethenes also can be used as electron acceptors in microbially mediated redox reactions.

As a part of both the August 1995 and May 1996 sampling events, analyses were performed on collected groundwater samples to determine the concentrations of geochemical indicators of intrinsic remediation. However, because the geochemical data set collected in May 1996 is incomplete, only data collected in August 1995 are discussed in the following paragraphs.

DO concentrations were measured at 45 of the 47 groundwater sampling locations monitored in August 1995. Table 5 summarizes DO concentrations measured at groundwater monitoring locations at FT-002 from August 1995 to May 1996. Figure 4 presents isopleth maps of important electron acceptors at the site, one of which shows the distribution of DO in groundwater in August 1995. Comparison of Figures 2 and 4 shows graphically that the two areas with elevated total BTEX concentrations, FT-002 and the east side of the flightline, have depleted DO concentrations, with the lowest DO concentrations occurring through the core of the dissolved BTEX plume at FT-002. A third area of depleted DO was observed in August 1995, just south of FT-002 along Perimeter Road. Elevated BTEX concentrations were not measured in this area; however, the depleted DO does not appear to be associated with dissolved contamination at FT-002. The correlation between depleted DO and elevated BTEX concentrations is a strong indication that aerobic biodegradation of the BTEX compounds is occurring at the site. The same relationship was observed for sampling data collected in December 1993 (Parsons ES, 1995). The greatest aerobic activity is expected to occur at the upgradient perimeter of the source area and along the fringes of the plume, because these are areas where BTEX-contaminated groundwater interacts with groundwater containing the highest concentrations of DO.

Concentrations of nitrate + nitrite (as nitrogen) were measured at 46 of the 47 locations sampled in August 1995. Nitrate + nitrite results measured at groundwater monitoring locations in August 1995 and May 1996 are presented on Table 5. An isopleth map for the August 1995 nitrate + nitrite results is also provided in Figure 4. Comparison of Figures 2 and 4 shows graphically that areas with elevated total BTEX concentrations have depleted nitrate + nitrite concentrations, with nitrate + nitrite concentrations below 0.2 milligrams per liter (mg/L) through the core of the dissolved BTEX plume originating from FT-002. As with DO, areas of depleted nitrate + nitrite were observed along the east side of the flightline and just south of FT-002. The same relationship was observed for sampling conducted in December 1993 (Parsons ES, 1995); however, the area with depleted nitrate + nitrite concentration extended further downgradient in 1995, reflecting the addition of downgradient groundwater monitoring wells/points to the site groundwater monitoring network. Depleted nitrate + nitrite concentrations in areas with depleted DO

# TABLE 5

## GROUNDWATER QUALITY DATA FOR GEOCHEMICAL INDICATORS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Temp. (°C) | pH | pE | Dissolved Oxygen (mg/L) [a] | NO$_2$+NO$_3$ as N [b] (mg/L) | Sulfate (mg/L) | Ferrous Iron (mg/L) | Methane (mg/L) | Alkalinity (CaCO$_3$) (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25-PLT-W2 | 8/95 | 13.6 | 7.8 | 4.99 | 6.7 | 0.53 | 31.3 | <0.05 | <0.001 | 134 | 112 | 182 |
| 26-PLT-W3 | 8/95 | 12.3 | 7.5 | 2.42 | 0.6 | 1.06 | 19.7 | NA [c] | <0.001 | 176 | 66 | 89.9 |
| 27-PLT-W4 | 8/95 | 13.2 | 7.0 | 0.95 | 0.1 | 0.19 | 42.7 | NA | 0.119 | 278 | 104 | 109 |
| 28-PLT-W4 | 8/95 | 20.8 | 7.9 | 4.99 | 7.5 | 1.36 | 19.3 | NA | <0.001 | 154 | 198 | 76 |
| 29-PLT-W5 | 8/95 | 16.0 | 7.9 | 3.23 | 0.8 | 0.14 | 17.2 | <0.05 | 0.088 | 130 | 68 | 23.8 |
| 30-PLT-W6 | 8/95 | 13.3 | 8.0 | -0.24 | 0.5 | 0.12 | 6.22 | <0.05 | 1.2 | 109 | 64 | 73 |
| 31-PLT-W11 | 8/95 | 14.8 | 7.5 | 2.21 | 0.7 | 0.16 | 12.6 | 0.4 | 13.9 | 388 | 226 | 36.6 |
| 32-PLT-W12 | 8/95 | 14.6 | 7.7 | 6.36 | 0.6 | 33.0 | 4.48 | <0.05 | 0.001 | 104 | 56 | 0.78 |
| 33-PLT-W12 | 8/95 | 12.1 | 7.6 | 6.30 | 0 | 7.99 | 6.1 | <0.05 | 0.285 | 168 | 68 | 4.12 |
| 34-PLT-W12 | 8/95 | 13.9 | 7.5 | 1.47 | 0.9 | 0.29 | 0.52 | 0.7 | 3.53 | 260 | 72 | 19.5 |
| 35-PLT-W13 | 8/95 | 16.4 | 7.8 | 6.34 | 0.4 | 10.4 | 14.7 | <0.05 | 0.115 | 185 | 36 | 3.29 |
| 36-PLT-W14 | 8/95 | 15.5 | 7.4 | 1.45 | 0.5 | 0.19 | 139 | 0.9 | 0.065 | 193 | 76 | 8.25 |
| 37-PLT-W15 | 8/95 | 19.5 | 6.4 | 2.40 | 1.4 | 0.16 | <0.5 | 52.5 | 13.9 | 404 | NA | 3.74 |
| 38-PLT-W15 | 8/95 | 17.5 | 7.9 | -0.66 | 0.9 | 0.14 | <0.5 | 0.1 | 4.4 | 90 | 88 | 9.03 |
| 39-PLT-W16 | 8/95 | 13.9 | 7.3 | 3.23 | 0.2 | 3.31 | 12.5 | <0.05 | 0.014 | 261 | 134 | 1.25 |
| 40-PLT-W7 | 8/95 | 13.5 | 6.8 | 1.71 | 0.5 | 0.16 | <0.5 | 29.8 | 21.4 | 526 | NA | 1.15 |
| 41-PLT-W10 | 8/95 | 14.7 | 7.3 | 4.99 | 0.2 | 4.24 | 12.4 | NA | 0.045 | 294 | 180 | 0.81 |
| 42-PLT-W9 | 8/95 | 15.2 | 7.3 | 4.50 | 0.4 | 0.62 | 17.8 | <0.05 | <0.001 | 280 | 198 | 16.4 |
| 43-PLT-W9 | 8/95 | 14.7 | 7.3 | 3.74 | 0.2 | 0.20 | 13.5 | 0.1 | <0.001 | 237 | 124 | 11.1 |
| 44-PLT-W1 | 8/95 | 15.2 | 7.6 | 6.41 | 7.5 | 0.62 | 13.6 | <0.05 | <0.001 | 231 | 84 | 42.5 |
| 45-PLT-W1 | 8/95 | 16.9 | 7.7 | 3.23 | 0.5 | 0.17 | 20.8 | <0.05 | 0.001 | 169 | 110 | 94.2 |
| 46-PLT-W8 | 8/95 | 16.3 | 7.1 | 3.06 | 0.6 | 0.18 | <0.5 | 0.8 | 0.009 | 279 | 242 | 58.5 |
| 47-PLT-W22 | 8/95 | NA | 8.6 | 5.44 | NA | 0.17 | 0.59 | <0.05 | 1.88 | 214 | NA | 0.85 |
| 49-PLT-W22 | 8/95 | 17.3 | 7.8 | 0.19 | 0.3 | 0.12 | 12.6 | <0.05 | 1.19 | 117 | 60 | 20.6 |
| 55-PLT-W17 | 8/95 | 14.8 | 7.6 | 1.54 | 0.3 | 0.13 | <0.5 | 0.3 | 3.09 | 128 | 46 | 12.5 |
| 56-PLT-W17 | 8/95 | 16.3 | 7.9 | 5.75 | 0.3 | 31.0 | 8.58 | 0.1 | 0.049 | 114 | 36 | 2.22 |

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TABLE 5 (continued)

## GROUNDWATER QUALITY DATA FOR GEOCHEMICAL INDICATORS
### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

| Sample Location | Sample Date | Temp. (°C) | pH | pE | Dissolved Oxygen (mg/L) [a] | NO$_2$+NO$_3$ as N [b] (mg/L) | Sulfate (mg/L) | Ferrous Iron (mg/L) | Methane (mg/L) | Alkalinity (CaCO$_3$) (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57-PLT-W17 | 8/95 | 15.8 | 7.6 | 5.34 | 0.1 | 31.1 | 9.52 | 0.1 | 0.045 | 117 | 102 | 4.46 |
| 58-PLT-W18 | 8/95 | 22.3 | 7.9 | 6.47 | 3.2 | 0.14 | 2.89 | NA | 2.14 | 137 | 102 | 1.13 |
| 59-PLT-W19 | 8/95 | 18.2 | 8.5 | 0.35 | 1.2 | 0.11 | 0.91 | < 0.05 | 1.25 | 212 | NA | 1.2 |
| 60-PLT-W19 | 8/95 | 16.5 | 8.3 | 1.88 | 0.2 | 0.11 | 7.28 | < 0.05 | 0.224 | 218 | NA | 3.36 |
| 61-PLT-W19 | 8/95 | 17.1 | 7.3 | 3.57 | 0.1 | 26.2 | 9.96 | 0.4 | 0.002 | 185 | 80 | 3.36 |
| 63-PLT-W20 | 8/95 | 17.4 | 7.2 | 5.93 | 0.1 | 34.8 | 9.32 | < 0.05 | 0.115 | 260 | 142 | 2.17 |
| 69-PLT-W21 | 8/95 | 16.9 | 6.7 | 2.05 | 0.1 | 1.14 | 4.88 | 13.3 | 0.594 | 425 | NA | 1.49 |
| 84-DA | 8/95 | 14.6 | 7.0 | 1.18 | 0.4 | 0.17 | < 0.5 | 14.5 | 0.088 | 252 | 330 | 33.9 |
| 84-DB | 8/95 | 12.1 | 6.9 | 1.28 | 0.4 | 0.17 | 17.3 | < 0.5 | 0.18 | 282 | 278 | 34.5 |
| 84-DC | 8/95 | 15.6 | 7.0 | 0.71 | 0.4 | 0.14 | 12.7 | 8.3 | < 0.001 | 98 | 124 | 15.6 |
| 84-DD | 8/95 | 15.2 | 7.0 | 1.37 | 0.4 | 0.17 | < 0.5 | 13.8 | 1.01 | 347 | 288 | 45.9 |
| MW-108 | 8/95 | 12.0 | 6.8 | 1.72 | 0.1 | 0.18 | 5.51 | 4.0 | 1.42 | 209 | NA | 62.6 |
| MW-02-006 | 8/95 | 13.8 | 7.2 | 1.34 | 0.5 | 0.18 | 30.9 | 2.6 | 0.005 | 160 | 148 | 219 |
| MW-02-019 | 8/95 | 14.0 | 7.2 | 0.57 | 0.2 | 0.18 | < 0.5 | 10.8 | 0.063 | 264 | 314 | 57.7 |
| MW-02-026 | 8/95 | 10.3 | 7.9 | 7.62 | 10.6 | 0.47 | 16.5 | < 0.05 | < 0.001 | 64 | 36 | 144 |
| MW-02-040 | 8/95 | 13.1 | 7.7 | 7.57 | 0.3 | 33.3 | 6.08 | < 0.05 | 0.03 | 159 | 98 | 4.76 |
| MW-02-041 | 8/95 | 15.1 | 7.5 | 7.49 | 0.5 | 2.01 | 2.15 | < 0.05 | 0.24 | 315 | 140 | 10.8 |
| MW-02-042 | 8/95 | 13.3 | 7.9 | 6.78 | 0.9 | 0.21 | < 0.5 | < 0.05 | 1.29 | 177 | 80 | 11.4 |
| MW-310 | 8/95 | 13.5 | 6.9 | 1.37 | 0.5 | 0.20 | < 0.5 | 15.3 | 0.305 | 330 | 374 | 47.9 |
| MW-336 | 8/95 | 15.0 | 7.9 | 0.76 | 0.6 | 0.16 | 12.1 | <0.05 | 0.198 | 134 | 76 | 20.1 |
| MW-02-019 | 5/96 | NA | NA | NA | NA | < 0.05 | < 0.5 | NA | 0.034 | NA | NA | 86.8 |
| MW-02-040 | 5/96 | NA | NA | NA | NA | 22.8 | 6.73 | NA | 0.029 | NA | NA | 4.94 |
| MW-02-041 | 5/96 | NA | NA | NA | NA | 0.24 | 1.33 | NA | 0.222 | NA | NA | 10.6 |
| MW-02-042 | 5/96 | NA | NA | NA | NA | < 0.05 | 0.63 | NA | 1.20 | NA | NA | 11 |
| 32-PLT-W12 | 5/96 | 7.8 | 7.8 | 6.88 | 0.1 | 39.5 | 3.76 | < 0.1 | 0.002 | 86 | NA | 0.77 |
| 33-PLT-W12 | 5/96 | NA | NA | NA | NA | 8.7 | 5.61 | NA | 0.051 | NA | NA | 2.28 |

TABLE 5 (concluded)

## GROUNDWATER QUALITY DATA FOR GEOCHEMICAL INDICATORS
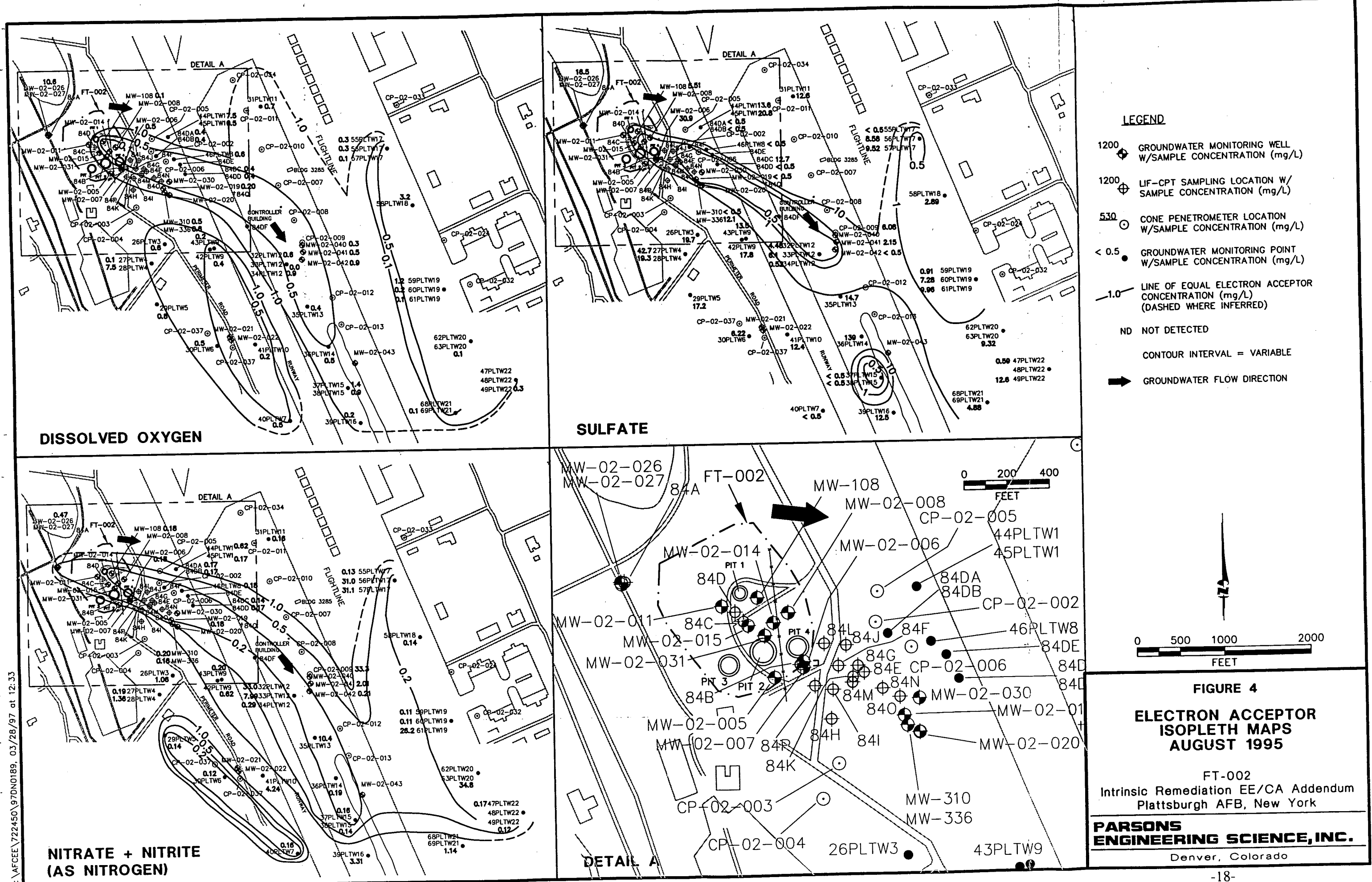### FT-002
### Intrinsic Remediation EE/CA Addendum
### Plattsburgh AFB, New York

| Sample Location | Sample Date | Temp. (°C) | pH | pE | Dissolved Oxygen (mg/L) [a] | NO$_2$+NO$_3$ as N [b] (mg/L) | Sulfate (mg/L) | Ferrous Iron (mg/L) | Methane (mg/L) | Alkalinity (CaCO$_3$) (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34-PLT-W12 | 5/96 | 7.8 | 6.6 | 6.88 | 0.1 | <0.05 | 0.96 | <0.1 | 1.790 | 86 | NA | 18.4 |
| 35-PLT-W13 | 5/96 | 8.7 | 8.2 | 4.12 | 0.2 | 9.49 | 14.4 | 0.11 | 0.044 | NA | NA | 2.63 |
| 44-PLT-W1 | 5/96 | NA | NA | NA | NA | 0.57 | 15.4 | NA | <0.001 | NA | NA | 65.2 |
| 45-PLT-W1 | 5/96 | NA | NA | NA | NA | <0.05 | 20.3 | NA | <0.001 | NA | NA | 95.2 |
| 46-PLT-W8 | 5/96 | NA | NA | NA | NA | <0.05 | <0.5 | NA | NA | 255 | NA | 51.6 |
| 59-PLT-W19 | 5/96 | NA | NA | NA | NA | 0.45 | 2.60 | NA | 0.909 | NA | NA | 1.24 |
| 60-PLT-W19 | 5/96 | NA | NA | NA | NA | 0.07 | 5.59 | NA | 0.280 | NA | NA | 3.38 |
| 61-PLT-W19 | 5/96 | NA | NA | NA | NA | 30.1 | 9.30 | NA | 0.003 | NA | NA | 2.44 |
| 63-PLT-W20 | 5/96 | NA | NA | NA | NA | 39.5 | 9.13 | NA | 0.017 | NA | NA | 2.88 |
| 84DA | 5/96 | NA | NA | NA | NA | <0.05 | 1.18 | NA | 0.074 | NA | NA | 49 |
| 84DB | 5/96 | NA | NA | NA | NA | <0.05 | <0.5 | NA | 0.275 | NA | NA | 45.9 |
| 84DC | 5/96 | 9.2 | 7.2 | 4.23 | 0.2 | <0.05 | 8.92 | 19.1 | 0.018 | 137 | NA | 27.5 |
| 84DD | 5/96 | 9.3 | 7.2 | 4.11 | 0.2 | <0.05 | <0.5 | 19.3 | 0.714 | 256 | NA | 57.2 |
| 84DF-22 | 5/96 | NA | NA | NA | NA | 4.92 | NA | NA | 0.045 | NA | NA | NA |
| 84DF-34 | 5/96 | NA | NA | NA | NA | 0.08 | 1.51 | NA | 0.617 | NA | NA | 13.6 |
| MW-310 | 5/96 | 10.3 | 6.9 | 2.81 | 0.1 | <0.05 | <0.5 | 16 | 0.339 | 300 | NA | 42.5 |
| MW-336 | 5/96 | NA | NA | NA | NA | 0.08 | 11.8 | NA | 0.138 | NA | NA | 20.3 |
| MW-02-108 | 5/96 | 12.1 | 7.1 | 4.00 | 0.5 | <0.05 | 0.96 | 45.6 | 1.6 | 330 | NA | 0.96 |

[a]  mg/L = milligrams per liter.

[b]  NO$_2$+NO$_3$ as N = nitrite and nitrate reported as mg/L of nitrogen.

[c]  NA = data not available.

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FIGURE 4

ELECTRON ACCEPTOR
ISOPLETH MAPS
AUGUST 1995

FT-002
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Plattsburgh AFB, New York

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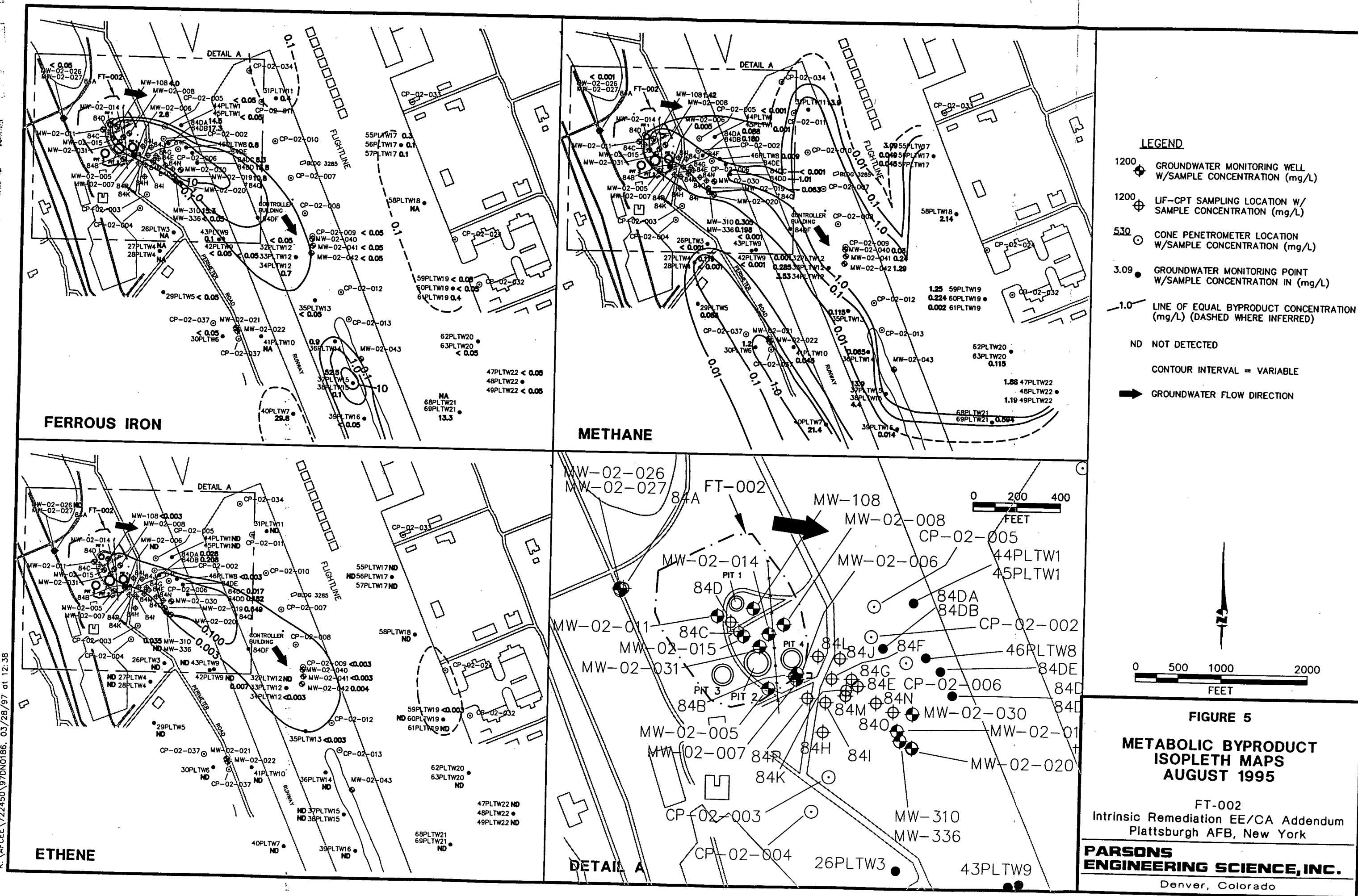ENGINEERING SCIENCE, INC.
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and elevated BTEX concentrations provides strong evidence that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of denitrification.

Ferrous iron concentrations were measured at 41 of the 47 sampled locations during the August 1995 sampling event. Table 5 lists ferrous iron concentrations measured at site groundwater monitoring locations in August 1995 and May 1996. Figure 5 presents isopleth maps showing the distribution of ferrous iron and other metabolic byproducts in groundwater in August 1995. Background concentrations of ferrous iron at the site are below the 0.05 mg/L detection limit; conversely, areas with elevated total BTEX concentrations have detectable concentrations of ferrous iron. The highest ferrous iron concentrations (52.5 and 29.8 mg/L) were detected in 37PLTW15 and 40PLTW7, respectively. These wells are located near the surface water area. However, elevated ferrous iron concentrations (greater than 10 mg/L) also were observed in the FT-002 source area monitoring wells. In addition, ferrous iron concentrations slightly above background concentrations were observed on the east side of the flightline. Coincident elevated ferrous iron and BTEX concentrations can be observed through a comparison of Figures 2 and 4. A similar relationship also was observed during the 1993 sampling event (Parsons ES, 1995). Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993); therefore, presence of ferrous iron strongly suggests that ferric iron is being used as an electron acceptor at the site. Furthermore, the coincident ferrous iron and BTEX plumes suggests that the reduction of ferric iron to ferrous iron is occurring during biodegradation of BTEX compounds.

Sulfate concentrations were measured at 46 of the 47 locations sampled in August 1995. Results for sulfate analyses performed at groundwater monitoring locations at FT-002 in August 1995 and May 1996 are summarized on Table 5. An isopleth map for the August 1995 sulfate results is provided on Figure 4. Comparison of Figures 2 and 4 shows graphically that the areas with the highest total BTEX concentrations have depleted sulfate concentrations. Three areas of depleted sulfate are observed within the dissolved plume originating from FT-002, along the east side of the flight line, and adjacent to the surface water area. Historically, the correlation between sulfate and BTEX concentrations has been noted only in the immediate vicinity of FT-002, but with the larger groundwater monitoring network other areas with sulfate concentrations below background were observed. The correlation of depleted sulfate concentrations with the highest BTEX concentrations provides strong evidence that anaerobic biodegradation of the BTEX compounds is occurring throughout the site through the microbially mediated process of sulfate reduction.

Methane concentrations measured at 46 of the 47 August 1995 sampling locations are presented on Figure 5. Methane concentrations measured at FT-002 groundwater monitoring locations between 1995 and 1996 are presented on Table 5. In areas with elevated total BTEX concentrations, August 1995 methane concentrations ranged from 0.001 mg/L to 3.53 mg/L. This relationship can be observed through a comparison of Figures 2 and 5. The presence of concomitant BTEX and methane plumes at the site is a strong indication that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of methanogenesis. Although background

FIGURE 5

METABOLIC BYPRODUCT
ISOPLETH MAPS
AUGUST 1995

FT-002
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Plattsburgh AFB, New York

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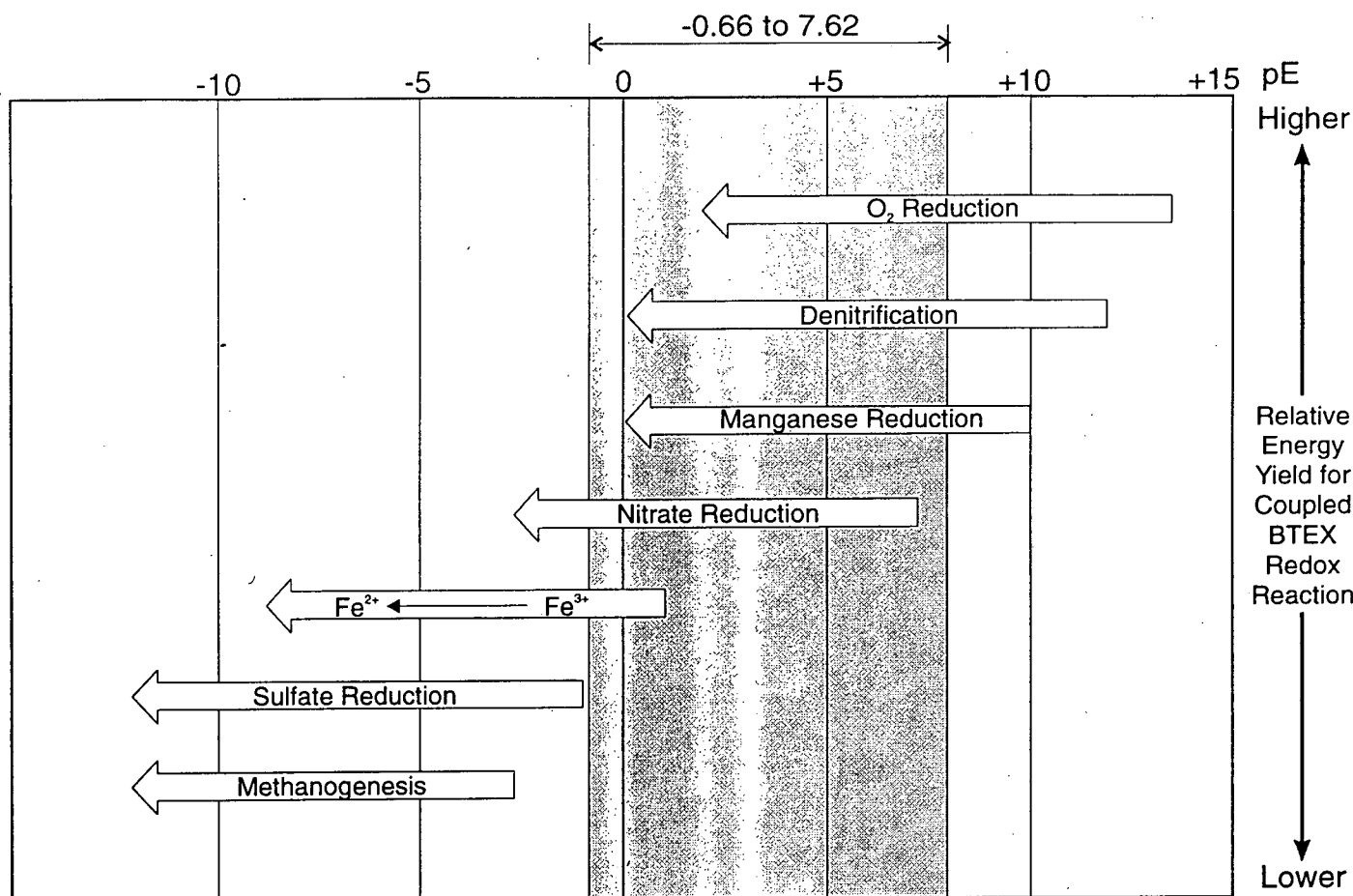ENGINEERING SCIENCE, INC.

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methane concentrations at the site generally are below the 0.001-mg/L detection level, the three highest methane concentrations (13.9 mg/L at 31PLTW11, 13.9 mg/L at 37PLTW17, and 21.4 at 40PLTW7) are not associated with the dissolved BTEX contamination present at FT-002 or along the east side of the flightline. Rather, the highest methane concentrations are associated with an unknown source near 31PLTW11, the surface water area (37PLTW15), and with possible low levels of dissolved contamination south of FT-002 (40PLTW7).

ORP, a measure of the relative tendency of a solution to accept or transfer electrons, was measured at 46 of the 47 wells sampled in the August 1995 sampling event. The dominant electron acceptor being reduced by microbes during BTEX oxidation is tied to the ORP of the groundwater. Measured site ORPs, expressed as potential energy (pE) values, are summarized on Table 5. The August 1995 pE values at FT-002 range from -0.66 to 7.62. Figure 6 shows which natural attenuation mechanisms can occur within this range of pE. Although measured site values are higher than the theoretical optimum levels for sulfate reduction and methanogenesis (Norris et al., 1994), this discrepancy is a common problem associated with measuring oxidizing potential using field instruments. It is likely that the platinum electrode probes are not sensitive to some of the redox couples (e.g., sulfate/sulfide, and carbon dioxide/methane). Many authors have noted that field measured redox data alone cannot be used to reliably predict the electron acceptors that may be operating at a site (Stumm and Morgan, 1981; Godsey, 1994; Lovley et al., 1994). Integrating redox measurements with analytical data on reduced and oxidized chemical species allows a more thorough and reasonable interpretation of which electron acceptors are being used to biodegrade site contaminants. Groundwater data collected at FT-002 suggests that that both sulfate reduction and methanogenesis are occurring even though the calculated pE range would exclude both processes.

Areas at the site with low ORPs coincide with areas characterized by high BTEX contamination; low DO, nitrate, and sulfate concentrations; and elevated ferrous iron and methane concentrations. This suggests that dissolved BTEX at the site may be subjected to a variety of biodegradation processes, including aerobic respiration, denitrification, iron reduction, sulfate reduction, and methanogenesis. The same relationships between ORP and electron acceptor/byproduct concentrations were noted in the December 1993 sampling event (Parsons ES, 1995).

## 2.5 Biodegradation of Chlorinated Solvents

Chlorinated solvents can be transformed, directly or indirectly, by biological processes (e.g., Bouwer et al., 1981; Wilson and Wilson, 1985; Miller and Guengerich, 1982; Nelson et al., 1986; Bouwer and Wright, 1988; Little et al., 1988; Mayer et al., 1988; Arciero et al., 1989; Cline and Delfino, 1989; Freedman and Gossett, 1989; Folsom et al., 1990; Harker and Kim, 1990; Alvarez-Cohen and McCarty, 1991a, 1991b; Destefano et al., 1991; Henry, 1991; McCarty et al., 1992; Hartmans and de Bont, 1992; McCarty and Semprini, 1994; Vogel, 1994). Biodegradation of CAHs is similar in principle to biodegradation of BTEX as described in Section 2.4; however, CAH degradation typically results from a more complex series of processes. Whereas BTEX is biodegraded in essentially one step by acting as an electron donor/carbon source, CAHs may undergo several types of biodegradation involving several steps. CAHs may undergo

**-0.66 to 7.62**

| -10 | -5 | 0 | +5 | +10 | +15 | pE |

Higher

O₂ Reduction

Denitrification

Manganese Reduction

Nitrate Reduction

$Fe^{2+}$ ← $Fe^{3+}$

Sulfate Reduction

Methanogenesis

Relative Energy Yield for Coupled BTEX Redox Reaction

Lower

## Notes

Range of pE (potential energy) measured at FT-002

1. These reactions would be expected to occur in sequence if the system is moving toward equilibrium.

2. These redox processes occur in order of their energy-yielding potential (provided microorganisms are available to mediate a specific reaction). Reduction of a highly oxidized species decreases the pE of the system.

3. The pE of the system determines which electron acceptors are available for oxidation.

4. Redox sequence is paralleled by an ecological succession of biological mediators.

Adapted from Stumm and Morgan, 1981.

cdr\draw\722450a.cdr ma 4/29/97

**FIGURE 6**

**SEQUENCE OF MICROBIALLY MEDIATED REDOX PROCESSES**

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biodegradation through three different pathways: use as an electron acceptor, use as an electron donor, or cometabolism, which is degradation resulting from exposure to a catalytic enzyme fortuitously produced during an unrelated microbial process. At a given site, one or all of these processes may be operating, although at many sites the use of CAHs as electron acceptors appears to be the most likely. Individual isopleth maps of TCE, cis-1,2-DCE, and vinyl chloride are presented for August 1995 and May 1996 on Figures 7 and 8. In August 1995 and May 1996, detected PCE concentrations were all less than 3 µg/L. A more complete description of the main types of biodegradation reactions affecting CAHs is presented in the following subsections.

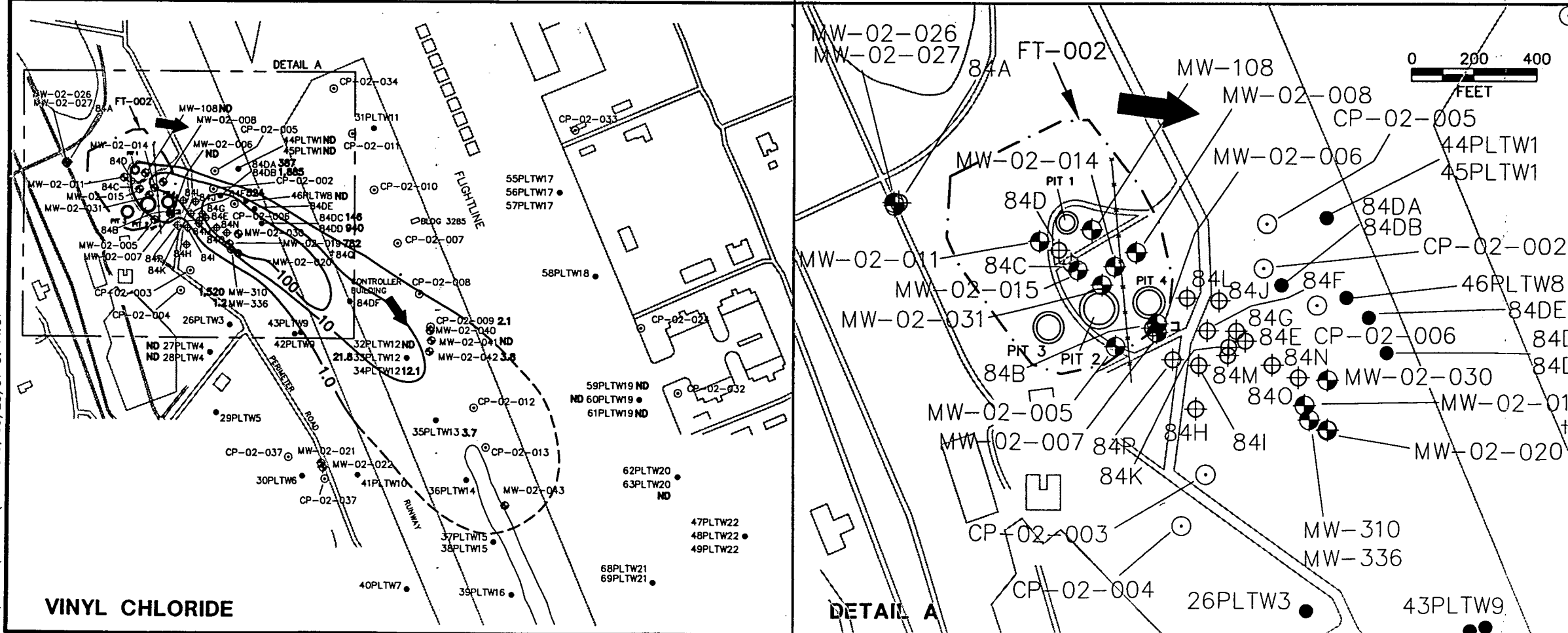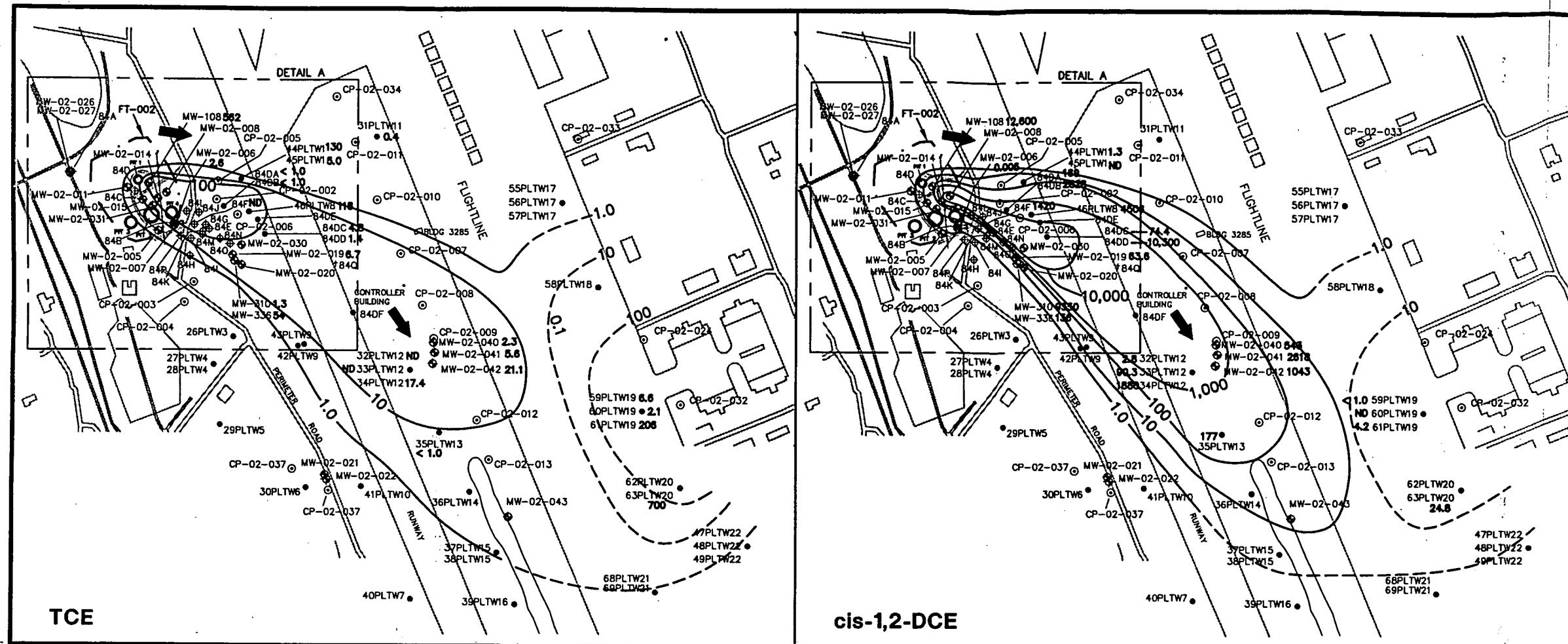### 2.5.1 Electron Acceptor Reactions (Reductive Dehalogenation)

Under anaerobic conditions, biodegradation of chlorinated solvents usually proceeds through a process called reductive dehalogenation. During this process, the halogenated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a halogen atom is removed and replaced with a hydrogen atom. In general, reductive dehalogenation occurs by sequential dehalogenation from PCE to TCE to DCE to vinyl chloride to ethene as shown in Figure 9. Depending upon environmental conditions, this sequence may be interrupted, with other processes then acting upon the products. During reductive dehalogenation, all three isomers of DCE can theoretically be produced; however, Bouwer (1994) reports that under the influence of biodegradation, cis-1,2-DCE is a more common intermediate than trans-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. Reductive dehalogenation of chlorinated solvent compounds is associated with the accumulation of daughter products and an increase in chloride.

Reductive dehalogenation affects each of the chlorinated ethenes differently. Of these compounds, PCE is the most susceptible to reductive dehalogenation because it is the most oxidized. Conversely, vinyl chloride is the least susceptible to reductive dehalogenation because it is the least oxidized of these compounds. The rate of reductive dehalogenation also has been observed to decrease as the degree of chlorination decreases (Vogel and McCarty, 1985; Bouwer, 1994). Murray and Richardson (1993) have postulated that this rate decrease may explain the accumulation of vinyl chloride in TCE plumes that are undergoing reductive dehalogenation.

In addition to being affected by the degree of chlorination of the CAH, reductive dehalogenation can also be controlled by the redox conditions of the site groundwater system. In general, reductive dehalogenation has been demonstrated under anaerobic nitrate- and sulfate-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of CAHs, occur under methanogenic conditions (Bouwer, 1994). Dehalogenation of PCE and TCE to DCE can proceed under mildly reducing conditions such as nitrate reduction or iron (III) reduction (Vogel et al., 1987), while the transformation of DCE to vinyl chloride, or the transformation from vinyl chloride to ethene requires more strongly reducing conditions (Freedman and Gossett, 1989; Destefano et al., 1991; DeBruin et al., 1992). Because CAH compounds are used as electron acceptors, there must be an appropriate source of carbon for microbial growth in order for reductive dehalogenation to occur (Bouwer, 1994). Potential carbon sources can include low-molecular-weight compounds (e.g., lactate, acetate, methanol, or glucose) present in natural organic matter, or fuel hydrocarbons such as BTEX. At FT-002, sulfate

This is a full-page technical figure consisting of four map panels (TCE, cis-1,2-DCE, VINYL CHLORIDE, and DETAIL A) with a legend and title block.

**LEGEND**

- 1200 ◈ GROUNDWATER MONITORING WELL W/SAMPLE CONCENTRATION (μg/L)
- 1200 ⊕ LIF-CPT SAMPLING LOCATION W/ SAMPLE CONCENTRATION (μg/L)
- 530 ⊙ CONE PENETROMETER LOCATION W/SAMPLE CONCENTRATION (μg/L)
- ND ● GROUNDWATER MONITORING POINT W/SAMPLE CONCENTRATION (μg/L)
- —1— LINE OF EQUAL ANALYTE CONCENTRATION (μg/L) (DASHED WHERE INFERRED)
- ND NOT DETECTED
- CONTOUR INTERVAL = VARIABLE
- ➤ GROUNDWATER FLOW DIRECTION

**TCE**

**cis-1,2-DCE**

**VINYL CHLORIDE**

**DETAIL A**

0 200 400 FEET

0 500 1000 2000 FEET

K:\AFCEE\722450\97DN0274, 03/28/97 at 2:12

TCE

cis-1,2-DCE

VINYL CHLORIDE

DETAIL A

0   200   400
FEET

0   500   1000   2000
FEET

### FIGURE 8

## CHLORINATED SOLVENT
## ISOPLETH MAPS
## MAY 1996

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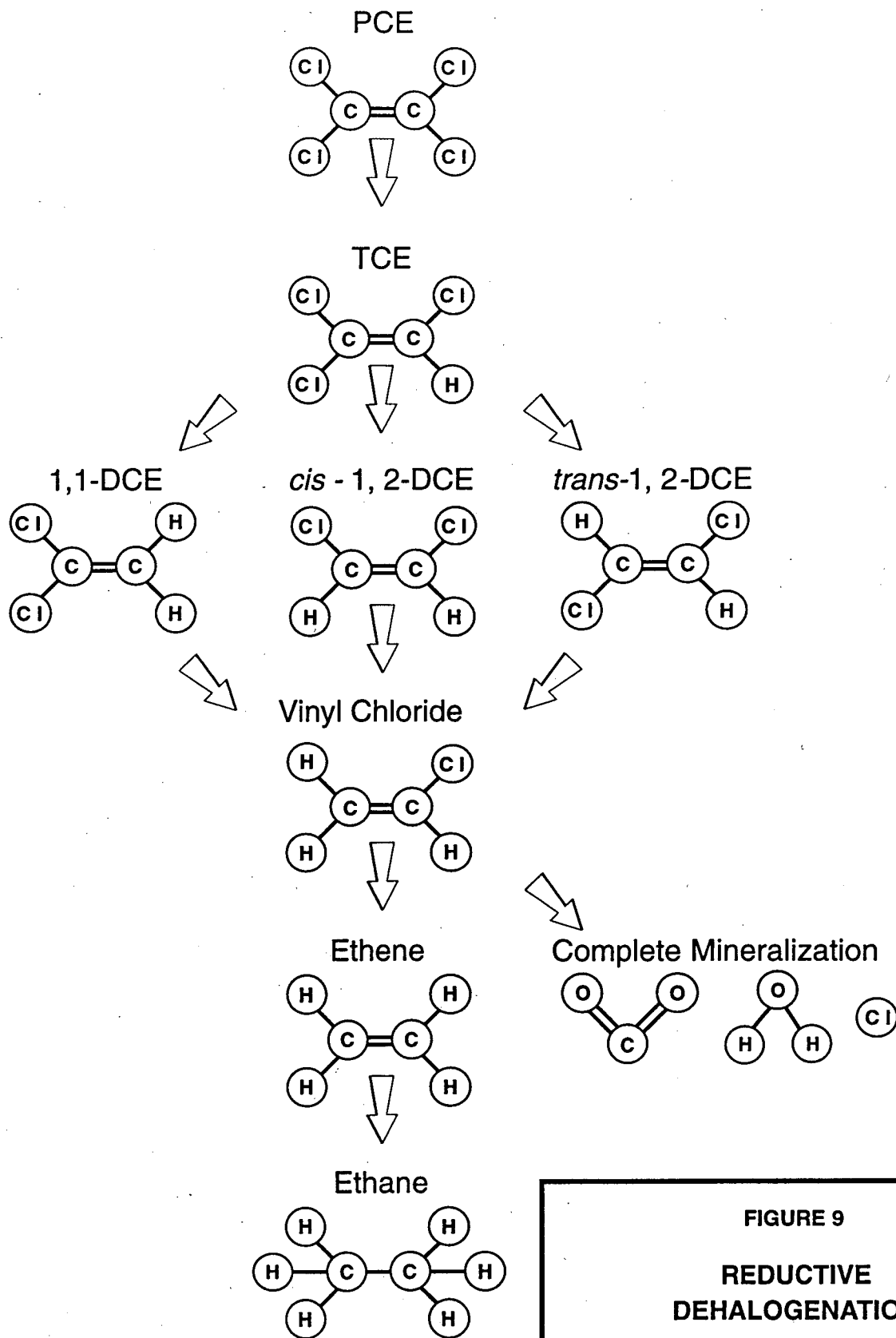**PCE**

**TCE**

**1,1-DCE**     *cis* - 1, 2-DCE     *trans*-1, 2-DCE

**Vinyl Chloride**

**Ethene**     **Complete Mineralization**

**Ethane**

**FIGURE 9**

**REDUCTIVE DEHALOGENATION**

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reduction, methanogenesis, and the corresponding low redox conditions in the core of contaminant plume support the possibility that reductive dehalogenation could occur at the site. This supposition is further supported by the presence of TCE daughter products in large concentrations. In fact, *cis*-1,2-DCE (a daughter product of the reductive dehalogenation of TCE) is present more frequently and at higher concentrations than any other CAH at the site. Furthermore, the presence of high concentrations of *cis*-1,2-DCE in association with low concentrations of *trans*-1,2-DCE in site groundwater provides further evidence of reductive dehalogenation. Because vinyl chloride has continuously represented 10 percent of the total dissolved chlorinated solvent contamination at the site, it is likely that reductive dehalogenation of *cis*-1,2-DCE also is occurring. Likewise, elevated ethene concentrations observed in site groundwater samples suggest that vinyl chloride is being further dehalogenated at FT-002, just downgradient from and in the source area at FT-002.

### 2.5.2 Electron Donor Reactions

Under aerobic conditions some CAH compounds can be utilized as the primary substrate (i.e., electron donor) in biologically mediated redox reactions (McCarty and Semprini, 1994). In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded CAH. In contrast to reactions in which the CAH is used as an electron acceptor, only the least oxidized CAHs can be utilized as electron donors in biologically mediated redox reactions. Davis and Carpenter (1990) describe the aerobic oxidation of vinyl chloride in groundwater. McCarty and Semprini (1994) describe investigations in which vinyl chloride was shown to serve as a primary substrate. In addition, Bradley and Chapelle (1996) show evidence of oxidation of vinyl chloride under iron-reducing conditions so long as there is sufficient bioavailable iron (III). Klier *et al.* (1996) write that naturally occurring microorganisms in soil and groundwater are capable of biodegrading DCE contamination by using DCE as a primary substrate (i.e. an electron donor). Murray and Richardson (1993) write that microorganisms are generally believed to be incapable of growth using TCE and PCE. Aerobic oxidation of vinyl chloride and DCE or ferric iron reduction of vinyl chloride may be characterized by contaminant mass loss, a decreasing molar ratio of DCE and/or vinyl chloride to other CAH compounds, and the presence of elevated carbon dioxide concentrations.

The disappearance of *cis*-1,2-DCE/vinyl chloride from the source area groundwater between December 1993 and May 1996 with a corresponding accumulation of vinyl chloride/ethene suggests that both *cis*-1,2-DCE and vinyl chloride are being reductively dehalogenated rather than oxidized as an electron donors. However, as shown on Figures 5 and 7, rapidly decreasing concentrations of vinyl chloride without a corresponding accumulation of dissolved ethene appear further downgradient of FT-002. Because conditions are less reducing in this area, vinyl chloride may be utilized as an electron donor, and therefore completely mineralized to carbon dioxide, water, and chloride ions. In addition, as dissolved BTEX concentrations continue to decrease at FT-002, and the groundwater system becomes less reducing, degradation pathways where *cis*-1,2-DCE and vinyl chloride are used as electron donors may become more important.

### 2.5.3 Cometabolism

When a CAH is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the CAH is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the CAH; rather, the cometabolic degradation of the CAH may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor (McCarty and Semprini, 1994).

Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation (Murray and Richardson, 1993; Vogel, 1994; McCarty and Semprini, 1994). Vogel (1994) further elaborates that the cometabolism rate increases as the degree of dehalogenation decreases. There is no evidence to either support or disallow that dissolved TCE, cis-1,2-DCE, and vinyl chloride concentrations are being reduced through cometabolic processes.

### 2.5.4 Chloride

Chloride concentrations also were measured in groundwater samples collected in August 1995 and May 1996. Chloride is a byproduct of the biodegradation of chlorinated solvents. Table 5 summarizes measured chloride concentrations. Because site chlorinated solvent concentrations are high, the increase in chloride concentrations that can be anticipated as a result of chlorinated solvent degradation should also be high. However, the variability in chloride concentrations in background locations at FT-002 masks any increase in chloride that may have occurred as a result of chlorinated solvent degradation. Instead, the presence of PCE and its daughter products (TCE, cis-1,2-DCE, vinyl chloride, and ethene) serve as a better indicator that biodegradation of CAHs is occurring.

### 2.5.4 Ethene

Dissolved ethene concentrations were measured in 46 of the 47 groundwater monitoring locations sampled in August 1995 (Table 4). Figure 5 presents an isopleth map of dissolved ethene concentrations observed in groundwater monitoring locations in August 1995. At sampling locations outside areas with known dissolved chlorinated solvent contamination, ethene concentrations were below the 0.003-mg/L detection limit. In areas with elevated vinyl chloride concentrations (Figure 7), August 1995 ethene concentrations ranged from 0.003 mg/L to 0.649 mg/L. Ethene concentrations above 0.100 mg/L were measured only in the area where total dissolved chlorinated solvent concentrations exceeded 10,000 µg/L. This relationship can be observed through a comparison of Figures 3 and 5. The presence of elevated dissolved ethene concentrations is a strong indication that reductive dehalogenation of vinyl chloride is occurring in the groundwater at FT-002.

## 2.6 Estimated Degradation Rates

The effectiveness of natural chemical attenuation processes at minimizing downgradient migration and eventually eliminating contaminant mass depends on the rates of microbial degradation processes (National Research Council, 1993; Salanitro, 1992; Wiedemeier *et al.*, 1995, Chapelle *et al.*, 1996). Use of the first-order approximation may be appropriate to estimate rates of dechlorination of CAH compounds if it is assumed that the utilization of the primary substrate (electron donor or BTEX) is not dependent on the presence of CAH compounds (electron acceptor). This may be a reasonable assumption if sufficient electron donor mass is available (i.e., significant BTEX concentrations) or if the microbial population capable of facilitating redox reactions between BTEX and CAHs is small and exhibiting low growth rates relative to other microbial populations. However, the use of first-order kinetics may not be appropriate when more than one substrate is limiting microbial degradation rates or when microbial mass is increasing or decreasing.

Site-specific first-order biodegradation rates for CAHs at FT-002 were calculated using methods presented by Buscheck an Alcantar (1995) and Moutoux *et al.* (1996). These rates are presented in Table 6, and the following sections briefly discuss the calculation methods.

### 2.6.1 Estimating First-Order Biodegradation for a Steady-State Plume

In order to ensure that some portion of observed decreases in contaminant concentrations can be attributed to biodegradation, measured contaminant concentrations must be corrected for the effects of dispersion, dilution, and sorption. Buscheck and Alcantar (1995) derive a relationship that allows calculation of first-order biodegradation rate constants for steady-state plumes. This method involves coupling the regression of contaminant concentration (plotted on a logarithmic scale) versus distance downgradient (plotted on a linear scale) to an analytical solution for one-dimensional, steady-state, contaminant transport that includes advection, dispersion, sorption, and biodegradation.

The relationship developed by Buscheck and Alcantar (1995) was applied to the data from all three sampling events. Calculated rates and corresponding half-lives are presented in Table 6. As noted above, this approach is best applied to steady-state plumes; if a plume is expanding, this method will yield an upper bound on the biodegradation rate. However, the CAH plume emanating from FT-002 appears to be stable based on the data presented herein.

### 2.6.2 Estimating First-Order Reductive Dehalogenation Rates

A convenient way to isolate the rate of biodegradation from other attenuation processes is to use as tracers compounds or elements associated with the contaminant plume that are relatively unaffected or predictably affected by biological processes occurring within the aquifer. When present, the trimethylbenzene isomers associated with fuels can serve as useful tracers under certain geochemical conditions (Wiedemeier *et al.*, 1995 and 1996a). Likewise, chloride, a degradation product of chlorinated solvent biodegradation has the potential to serve as a useful tracer (Wiedemeier *et al.*, 1996b). A third method, described

**TABLE 6**

**ESTIMATED FIRST-ORDER BIODEGRADATION RATES**

**FT-002**

**Intrinsic Remediation EE/CA Addendum**

**Plattsburgh AFB, New York**

| Date | Steady-State Plume Biodegradation[a] (day$^{-1}$) | Steady-State Plume Half-Life (years) | Reductive Dehalogenation[b] (day$^{-1}$) | Reductive Dehalogenation Half-Life (years) |
|---|---|---|---|---|
| December 1993 | 0.00017 | 11.2 | 0.000112 | 17.0 |
| August 1995 | 0.00025 | 7.6 | 0.000063 | 30.1 |
| May 1996 | 0.00025 | 7.6 | 0.000033 | 57.5 |

[a] Calculated using method of Buscheck and Alcantar (1995).
[b] Calculated using method of Moutoux *et al.* (1996).

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by Moutoux et al. (1996), uses CAHs and their daughter products as tracers. This can be done by using the double-bonded carbon "core" of the chlorinated ethenes as a tracer. As reductive dehalogenation proceeds, the compounds are not destroyed; instead, a chlorine atom is replaced by a hydrogen atom, but the carbon "core" remains intact. The "core" is affected by the same non-destructive mechanisms as the compounds, and therefore is a good tracer.

The rates derived using the method of Moutoux et al. (1996) are reductive dehalogenation rates. Rates calculated from FT-002 data and the corresponding half-lives are presented in Table 6. Use of this method is appropriate because anaerobic, reducing conditions with large daughter product concentrations prevail through much of the CAH plume at FT-002.

However, the rate estimate does not adequately assess the total biodegradation rate if biodegradation mechanisms other than reductive dechlorination are operant. Alternate biodegradation avenues are available for lower molecular weight solvents such as vinyl chloride as groundwater conditions become less reducing. For instance, at FT-002 site, groundwater geochemistry becomes less reducing between 2,000 and 2,500 feet downgradient from the source area; therefore, a reductive dechlorination rate cannot be calculated beyond this point. The combination of slowing reductive dechlorination rates and the possible destruction of vinyl chloride (and perhaps other parent and daughter products) by alternate biodegradation processes renders the technique inappropriate along the downgradient plume extent.

## 3.0 CONCLUSIONS

The purpose of this addendum is to supplement data presented in the original EE/CA and to more thoroughly document the extent and degradation of chlorinated solvents dissolved in the groundwater at FT-002. The original recommendations made in the EE/CA remain valid; however, as noted in this addendum, model predictions were made before the extent of BTEX contamination was fully defined. Therefore, model predictions are inaccurate at estimating extent of dissolved BTEX contamination, but appear to accurately predict the decrease in the magnitude of dissolved BTEX concentrations in the source area over time. It is also important to note that the dissolved BTEX plume is likely to never surpass the dissolved chlorinated solvent plume.

Results from the site characterization and long-term groundwater monitoring conducted during August 1995 and May 1996 continue to support the occurrence of intrinsic bioremediation of dissolved BTEX at FT-002 and the surrounding area. Two primary lines of evidence include the decrease in total dissolved BTEX concentrations in the source area and the distribution of electron acceptors/metabolic byproducts that are involved in biologically mediated redox reactions. Future long-term monitoring (LTM) will help monitor the effects of natural attenuation on the BTEX and CAH plume, and changes that may occur as these processes continue to alter site geochemistry. LTM will also help monitor temporal changes in the contaminant source due to remediation and weathering processes.

Groundwater contaminant data also suggests that the dissolved chlorinated solvent plume has reached steady state, and continues to be biodegraded through the process of reductive dehalogenation. The consistency in the relative percentages of individual chlorinated solvents over time suggests that reductive dechlorination rates continue to control plume migration. In addition, the slight temporal decrease in dissolved chlorinated solvent concentrations just downgradient from FT-002 (MW-02-40, MW-02-41, and MW-02-42) suggest that not only is the contaminant plume at steady state, but that the extent of highly contaminated groundwater (>1,000 $\mu$g/L total chlorinated ethenes) has begun to shrink. Future LTM will also help define the downgradient extent of the chlorinated solvent plume, help monitor the effectiveness of reductive dechlorination, and possibly document the aerobic oxidation of cis-1,2-DCE and vinyl chloride at the fringes of the contaminant plume.

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# APPENDIX A

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR BTEX AND TMB COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Benzene (ppb)[b] | Toluene (ppb) | Ethylbenzene (ppb) | p-xylene (ppb) | m-xylene (ppb) | o-xylene (ppb) | Total Xylenes (ppb) | Total BTEX (ppb) | 1,3,5-TMB[c] (ppb) | 1,2,4-TMB[d] (ppb) | 1,2,3-TMB[e] (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 84B | Dec. 1993 | 207.22 | 71 | 52.9 | 16.2 | 8.53 | 24.7 | 14.9 | 48.13 | 188.23 | < 0.5[f] | 2.24 | 2.46 |
| 84B | Dec. 1993 | 186.02 | < 0.5[g] | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| 84E | Dec. 1993 | 210.52 | 264 | 525 | 354 | 303 | 671 | 268 | 1242 | 2385 | 54 | 149 | 60.6 |
| 84E | Dec. 1993 | 190.52 | 448 | 944 | 606 | 553 | 979 | 448 | 1980 | 3978 | 78.6 | 227 | 120 |
| 84E | Dec. 1993 | 174.52 | 6.65 | < 0.5 | 7.26 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 13.91 | < 0.5 | < 0.5 | < 0.5 |
| 84F | Dec. 1993 | 207.26 | 178 | 443 | 263 | 255 | 374 | 249 | 878 | 1762 | 57.4 | 159 | 80.7 |
| 84F | Dec. 1993 | 197.26 | 161 | 363 | 250 | 219 | 461 | 164 | 844 | 1618 | 29.7 | 97.1 | 49.6 |
| 84F | Dec. 1993 | 192.26 | 83.4 | 107 | 166 | 136 | 226 | 78.2 | 440.2 | 796.6 | 17.3 | 65.6 | 33.2 |
| 84F | Dec. 1993 | 177.26 | 1.59 | < 0.5 | 11.3 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 12.89 | < 0.5 | < 0.5 | < 0.5 |
| 84M | Dec. 1993 | 203.4 | 183 | 277 | 449 | 480 | 1010 | 352 | 1842 | 2751 | 88.6 | 242 | 130 |
| 84M | Dec. 1993 | 183.4 | 16.3 | 1.03 | 15.7 | 6.25 | < 0.5 | < 0.5 | < 0.5 | 39.28 | < 0.5 | < 0.5 | < 0.5 |
| 84N | Dec. 1993 | 204.15 | 416 | 1090 | 488 | 429 | 902 | 379 | 1710 | 3704 | 70.8 | 198 | 99.6 |
| 84N | Dec. 1993 | 184.15 | 287 | 241 | 318 | 278 | 607 | 223 | 1108 | 1954 | 37.8 | 102 | 56.8 |
| 84O | Dec. 1993 | 203.1 | 296 | 309 | 329 | 294 | 574 | 244 | 1112 | 2046 | 56.9 | 149 | 71.9 |
| 84O | Dec. 1993 | 188.1 | 242 | 78.7 | 273 | 233 | 512 | 193 | 938 | 1531.7 | 32.6 | 89.9 | 50 |
| MW-02-005 | Dec. 1993 | 213.42 | 1.27 | < 0.5 | 107 | 37.1 | 7.69 | 1.27 | 46.06 | 154.33 | 2.57 | 5.48 | 7.65 |
| MW-02-006 | Dec. 1993 | 214.78 | 7.32 | 101 | 144 | 200 | 515 | 283 | 998 | 1250.3 | 180 | 588 | 306 |
| MW-02-006 (dup) | Dec. 1993 | 214.78 | 7.96 | 263 | 139 | 147 | 367 | 187 | 701 | 1111 | 43.5 | 122 | 66.3 |
| MW-02-007 | Dec. 1993 | 179.69 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-014 | Dec. 1993 | 216.01 | 342 | 1560 | 808 | 795 | 1790 | 715 | 3300 | 6010 | 111 | 352 | 189 |
| MW-02-015 | Dec. 1993 | 217.25 | 30.2 | 303 | 161 | 183 | 512 | 213 | 908 | 1402.2 | 93 | 255 | 145 |
| MW-02-019 | Dec. 1993 | 211.43 | 321 | 327 | 433 | 352 | 703 | 263 | 1318 | 2399 | 65.9 | 179 | 93.2 |
| MW-02-020 | Dec. 1993 | 195.16 | 286 | 148 | 563 | 534 | 1190 | 419 | 2143 | 3138 | 116 | 322 | 157 |
| MW-02-021 | Dec. 1993 | 181.85 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-026 | Dec. 1993 | 219.6 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 3.69 | 2.55 | 6.24 | 6.24 | 1.19 | 1.96 | 1.66 |
| MW-02-027 | Dec. 1993 | 186.72 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 0.997 | < 0.5 | 0.997 | 0.997 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-030 | Dec. 1993 | 179.55 | 16.5 | 1.06 | 19.9 | 3 | 4.72 | 1.48 | 9.2 | 46.66 | < 0.5 | 1.1 | < 0.5 |
| MW-02-030 (dup) | Dec. 1993 | 179.55 | 19.6 | 1.05 | 21.6 | 2.37 | 3.04 | 0.969 | 6.379 | 48.639 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-040 | Dec. 1993 | 184.02 | 1.93 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 1.93 | < 0.5 | < 0.5 | < 0.5 |

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR BTEX AND TMB COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Benzene (ppb)[b] | Toluene (ppb) | Ethylbenzene (ppb) | p-xylene (ppb) | m-xylene (ppb) | o-xylene (ppb) | Total Xylenes (ppb) | Total BTEX (ppb) | 1,3,5- TMB[c] (ppb) | 1,2,4- TMB[d] (ppb) | 1,2,3- TMB[e] (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MW-02-041 | Dec. 1993 | 169.05 | 40.7 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 0.914 | 0.914 | 41.614 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-042 | Dec. 1993 | 153.26 | 56.9 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | 56.9 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-043 | Dec. 1993 | 165.47 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-043 (dup) | Dec. 1993 | 165.47 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| MW-02-044 | Dec. 1993 | 166.24 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| Field Blank | Dec. 1993 | | 2.42 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| CP-02-003 | 1991 | 217.15 | 2 | NR[h] | NR | NR | NR | NR | NR | 2 | NR | NR | NR |
| CP-02-003 | 1991 | 208.15 | 15 | NR | 15 | NR | NR | NR | NR | 30 | NR | NR | NR |
| CP-02-003 | 1991 | 199.15 | NR | NR | 66 | NR | NR | NR | NR | 66 | NR | NR | NR |
| CP-02-003 | 1991 | 185.15 | NR | NR | 16 | NR | NR | NR | NR | 16 | NR | NR | NR |
| CP-02-008 | 1991 | 153.31 | 240 | NR | NR | NR | NR | NR | NR | 240 | NR | NR | NR |
| CP-02-009 | 1991 | 174.31 | 2.8 | NR | NR | NR | NR | NR | NR | 2.8 | NR | NR | NR |

a/ feet msl = feet above mean sea level

b/ ppb = parts per billion

c/ 1,3,5 TMB = 1,3,5 trimethylbenzene

d/ 1,2,4 TMB = 1,2,4 trimethylbenzene

e/ 1,2,3 TMB = 1,2,3 trimethylbenzene

f/ < 0.5 = below practical limit of quantitation

g/ < 0.5 = not detected

h/ NR = not reported

Note: Background sampling locations are placed in boldface

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Vinyl Chloride (ppb)[b] | trans-DCE[c] (ppb) | cis-DCE[d] (ppb) | Lab Qual. Flag | TCE[e] (ppb) | Total Chlorinated Solvents (ppb) | Fuel Carbon (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| 84B | Dec. 1993 | 207.22 | < 0.5[f] | < 0.5 | 300 | | 5.6 | 305.6 | 296 |
| 84B | Dec. 1993 | 186.02 | < 0.5 | < 0.5 | 3.1 | | < 0.5 | 3.1 | < 0.5 |
| 84E | Dec. 1993 | 210.52 | 1020 | 1.2 | 752 | | < 0.5 | 1773.7 | 3060 |
| 84E (dup) | Dec. 1993 | 210.52 | 1010 | 1.1 | 710 | | < 0.5 | 1721.1 | NR |
| 84E | Dec. 1993 | 190.52 | 25.7 | 1.3 | 10000 | > | 0.7 | 10027.7 | 7560 |
| 84E (dup) | Dec. 1993 | 190.52 | 22.4 | 1.3 | 10900 | 1/2 dil[h] | 1 | 10924.7 | NR |
| 84E | Dec. 1993 | 174.52 | < 0.5 | < 0.5 | 160 | | 20.6 | 180.6 | 74.3 |
| 84F | Dec. 1993 | 207.26 | 2080 | < 0.5 | 9.1 | | < 0.5 | 2089.1 | 2570 |
| 84F (dup) | Dec. 1993 | 207.26 | 1610 | < 0.5 | 8.3 | | < 0.5 | 1618.3 | NR |
| 84F | Dec. 1993 | 197.26 | 3.6 | < 0.5 | 6370 | | < 0.5 | 6373.6 | 3360 |
| 84F | Dec. 1993 | 192.26 | 5.7 | < 0.5 | 4310 | | 0.6 | 4316.3 | 1930 |
| 84F | Dec. 1993 | 177.26 | < 0.5 | < 0.5 | 69 | | 12.8 | 81.8 | 53.1 |
| 84M | Dec. 1993 | 203.4 | 1050 | < 0.5 | 1320 | | < 0.5 | 2370 | 4300 |
| 84M (lab dup) | Dec. 1993 | 203.4 | 995 | < 0.5 | 1250 | | < 0.5 | 2245 | NR |
| 84M | Dec. 1993 | 183.4 | < 0.5 | < 0.5 | 240 | | 9.1 | 249.1 | 124 |
| 84N | Dec. 1993 | 204.15 | 1710 | < 0.5 | 208 | | < 0.5 | 1918 | 4620 |
| 84N (dup) | Dec. 1993 | 204.15 | 1550 | < 0.5 | 209 | | < 0.5 | 1759 | NR |
| 84N | Dec. 1993 | 184.15 | 3.1 | 1 | 5850 | | < 0.5 | 5854.1 | 4200 |
| 84O | Dec. 1993 | 203.1 | 486 | < 0.5 | 3140 | | 2.8 | 3628.8 | 3370 |
| 84O | Dec. 1993 | 188.1 | < 0.5 | < 0.5 | 6710 | | < 0.5 | 6710 | 3280 |
| 84O (lab dup) | Dec. 1993 | 188.1 | < 0.5 | < 0.5 | 6650 | | < 0.5 | 6650 | NR |
| 84-Field Blank | Dec. 1993 | N/A[f] | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | 4.77 |
| MW-02-005 | Dec. 1993 | 213.42 | < 0.5 | < 0.5 | 4 | | 0.6 | 4.6 | 844 |
| MW-02-006 | Dec. 1993 | 214.78 | < 0.5 | < 0.5 | 28.7 | | 0.6 | 29.3 | 3620 |
| MW-02-007 | Dec. 1993 | 179.69 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | < 0.5 |

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS

### FT-002

#### Intrinsic Remediation EE/CA Addendum

#### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Vinyl Chloride (ppb)[b] | trans-DCE[c] (ppb) | cis-DCE[d] (ppb) | Lab Qual. Flag | TCE[e] (ppb) | Total Chlorinated Solvents (ppb) | Fuel Carbon (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| MW-02-007 (dup) | Dec. 1993 | 179.69 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | NR |
| MW-02-014 | Dec. 1993 | 216.01 | 4.5 | < 0.5 | 9050 | | 1030 | 10084.5 | 9940 |
| MW-02-014 (dup) | Dec. 1993 | 216.01 | 3.7 | < 0.5 | 9760 | | 560 | 10323.7 | NR |
| MW-02-015 | Dec. 1993 | 217.25 | < 0.5 | < 0.5 | 110 | | 1330 | 1440 | 2800 |
| MW-02-019 | Dec. 1993 | 211.43 | 384 | < 0.5 | 3540 | | 1.9 | 3925.9 | 4410 |
| MW-02-020 | Dec. 1993 | 195.16 | 9.8 | < 0.5 | 8530 | | 1.4 | 8541.2 | 7580 |
| MW-02-021 | Dec. 1993 | 181.85 | < 0.5 | < 0.5 | 2 | | 4.6 | 6.6 | < 0.5 |
| MW-02-021 (lab dup) | Dec. 1993 | 181.85 | < 0.5 | < 0.5 | 2.1 | | 4.5 | 6.6 | NR |
| MW-02-026 | Dec. 1993 | 219.6 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | 25.7 |
| MW-02-027 | Dec. 1993 | 186.72 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | < 0.5 |
| MW-02-030 | Dec. 1993 | 179.55 | < 0.5 | 0.7 | 185 | | 79.7 | 265.4 | 145 |
| MW-02-040 | Dec. 1993 | 184.02 | 0.8 | < 0.5 | 339 | | 3.1 | 342.9 | 92 |
| MW-02-041 | Dec. 1993 | 169.05 | < 0.5 | < 0.5 | 5230 | | 30.7 | 5260.7 | 18500 |
| MW-02-042 | Dec. 1993 | 153.26 | 2.2 | 1.1 | 1570 | | 98.5 | 1671.8 | 469 |
| MW-02-042 (lab dup) | Dec. 1993 | 153.26 | 2.3 | 1 | 1570 | | 91 | 1664.3 | NR |
| MW-02-043 | Dec. 1993 | 165.47 | < 0.5 | < 0.5 | 10.6 | | 373 | 383.6 | < 0.5 |
| MW-02-044 | Dec. 1993 | 166.24 | < 0.5 | < 0.5 | 2.9 | | 135 | 137.9 | < 0.5 |
| MW-02-043 | May 1994 | 165.47 | 1.65 | 2.49 | 11.4 | | 303 | 318.5 | NR |
| MW-02-043 (dup) | May 1994 | 165.47 | 2.14 | 3.32 | 13.9 | | 321 | 340.4 | NR |
| 84Q-2 | May 1994 | 211.92 | 1.18 | 1.08 | 156 | | 2.79 | 161.1 | NR |
| 84Q-2 (dup) | May 1994 | 211.92 | < 0.5 | 1.79 | 155 | | 3.07 | 159.9 | NR |
| 84Q-3 | May 1994 | 199.42 | 488 | 25.6 | 601 | | 6.94 | 1121.5 | NR |
| 84Q-4 | May 1994 | 192.42 | 161 | 228 | 3150 | | 21.5 | 3560.5 | NR |
| 84Q-5 | May 1994 | 182.92 | 32.3 | 33.8 | 908 | | 129 | 1103.1 | NR |
| 84Q-6 | May 1994 | 175.42 | 28.5 | 11.9 | 1120 | | 104 | 1264.4 | NR |
| Sparge Pt 1 (1) | May 1994 | 14' bgs* | 233 | 34.9 | 840 | | 4.44 | 1112.3 | NR |

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Vinyl Chloride (ppb)[b] | trans-DCE[c] (ppb) | cis-DCE[d] (ppb) | Lab Qual. Flag | TCE[e] (ppb) | Total Chlorinated Solvents (ppb) | Fuel Carbon (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| Sparge Pt 1 (1) (dup) | May 1994 | 14' bgs* | 232 | 37.4 | 837 | | 5.12 | 1111.5 | NR |
| Sparge Pt 1 (2) | May 1994 | 24' bgs* | 167 | 228 | 1870 | | 23.1 | 2288.1 | NR |
| Sparge Pt 2 | May 1994 | 14' bgs* | 29.9 | 137 | 731 | | 162 | 1059.9 | NR |
| Sparge Pt 3 | May 1994 | 14' bgs* | 537 | 52.5 | 578 | | 10.4 | 1177.9 | NR |
| Sparge Pt 4 (1) | May 1994 | 14' bgs* | 459 | 67.1 | 848 | | 9.87 | 1383.9 | NR |
| Sparge Pt 4 (2) | May 1994 | 24' bgs* | 195 | 233 | 3460 | | 14.8 | 3902.8 | NR |
| Sparge Pt 5 | May 1994 | 14' bgs* | 717 | 55.8 | 324 | | 4.73 | 1101.5 | NR |
| CP-02-002 | 1991 | 230.92 | NR[g] | NR | NR | | 47 | 47 | NR |
| CP-02-002 | 1991 | 198.92 | NR | NR | 1.1 | | 21 | 22.1 | NR |
| CP-02-002 | 1991 | 192.92 | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-003 | 1991 | 217.15 | NR | NR | 120 | | NR | 120 | NR |
| CP-02-003 | 1991 | 208.15 | NR | NR | 210 | | NR | 210 | NR |
| CP-02-003 | 1991 | 199.15 | NR | NR | 160 | | NR | 160 | NR |
| CP-02-003 | 1991 | 185.15 | NR | NR | 84 | | NR | 84 | NR |
| CP-02-003 | 1991 | 173.15 | NR | NR | 1.2 | | NR | 1.2 | NR |
| CP-02-004 | 1991 | 210.15 | NR | NR | NR | | 1 | 1 | NR |
| CP-02-004 | 1991 | 194.15 | NR | NR | NR | | 20 | 20 | NR |
| CP-02-004 | 1991 | 184.15 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-004 | 1991 | 176.15 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-005 | 1991 | 237.68 | NR | NR | NR | | 6.6 | 6.6 | NR |
| CP-02-005 | 1991 | 226.68 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-005 | 1991 | 210.68 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-005 | 1991 | 206.68 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-005 | 1991 | 202.68 | NR | NR | NR | | < 0.5 | < 0.5 | NR |
| CP-02-006 | 1991 | 247.37 | NR | NR | NR | | 630 | 630 | NR |

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Vinyl Chloride (ppb)[b] | trans-DCE[c] (ppb) | cis-DCE[d] (ppb) | Lab Qual. Flag | TCE[e] (ppb) | Total Chlorinated Solvents (ppb) | Fuel Carbon (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| CP-02-006 | 1991 | 238.37 | NR | NR | 180 | | 3400 | 3580 | NR |
| CP-02-006 | 1991 | 229.37 | NR | NR | 850 | | 3500 | 4350 | NR |
| CP-02-006 | 1991 | 218.37 | NR | NR | NR | | 430 | 430 | NR |
| CP-02-006 | 1991 | 207.37 | NR | NR | NR | | 330 | 330 | NR |
| CP-02-007 | 1991 | 187.81 | NR | NR | NR | | 12 | 12 | NR |
| CP-02-007 | 1991 | 178.81 | NR | NR | NR | | 54 | 54 | NR |
| CP-02-007 | 1991 | 164.81 | NR | NR | 240 | | 4900 | 4900 | NR |
| CP-02-007 | 1991 | 153.81 | NR | NR | NR | | 26 | 26 | NR |
| CP-02-008 | 1991 | 182.31 | NR | NR | 670 | | 52 | 722 | NR |
| CP-02-008 | 1991 | 167.31 | NR | NR | 2000 | | 1500 | 3500 | NR |
| CP-02-008 | 1991 | 158.31 | NR | NR | 1700 | | 3200 | 4900 | NR |
| CP-02-008 | 1991 | 153.31 | NR | NR | 510 | | 3300 | 3810 | NR |
| CP-02-009 | 1991 | 193.31 | NR | NR | 14 | | NR | 14 | NR |
| CP-02-009 | 1991 | 181.31 | NR | NR | 19 | | NR | 19 | NR |
| CP-02-009 | 1991 | 174.31 | NR | NR | 700 | 1/20 dil | NR | 700 | NR |
| CP-02-009 | 1991 | 165.31 | NR | NR | 10000 | 1/1000 dil | NR | 10000 | NR |
| CP-02-009 | 1991 | 155.31 | NR | NR | 790 | 1/100 dil | NR | 790 | NR |
| CP-02-009 | 1991 | 149.31 | NR | NR | 20 | 1/10 dil | NR | 20 | NR |
| CP-02-010 | 1991 | 179.76 | NR | NR | NR | | 5.3 | 5.3 | NR |
| CP-02-010 | 1991 | 163.76 | NR | NR | 19 | | 5.5 | 24.5 | NR |
| CP-02-011 | 1991 | 174.51 | NR | NR | NR | | 1.4 | 1.4 | NR |
| CP-02-011 | 1991 | 161.5 | NR | NR | 17 | | 6.2 | 23.2 | NR |
| CP-02-012 | 1991 | 194.87 | NR | NR | 42 | | 19 | 61 | NR |
| CP-02-012 | 1991 | 184.87 | NR | NR | 2100 | | 1500 | 3600 | NR |
| CP-02-012 | 1991 | 175.87 | NR | NR | 8.7 | | 6.4 | 15.1 | NR |

# APPENDIX A

## GROUNDWATER QUALITY DATA FOR CHLORINATED SOLVENTS AND OTHER FUEL-RELATED COMPOUNDS

### FT-002

### Intrinsic Remediation EE/CA Addendum

### Plattsburgh AFB, New York

| Sample Location | Sample Date | Sample Elevation (feet msl)[a] | Vinyl Chloride (ppb)[b] | trans-DCE[c] (ppb) | cis-DCE[d] (ppb) | Lab Qual. Flag | TCE[e] (ppb) | Total Chlorinated Solvents (ppb) | Fuel Carbon (ppb) |
|---|---|---|---|---|---|---|---|---|---|
| CP-02-013 | 1991 | 189.99 | NR | NR | NR | | 190 | 190 | NR |
| CP-02-013 | 1991 | 181.99 | NR | NR | 3.7 | | 8.4 | 12.1 | NR |
| CP-02-024 | 1991 | N/A | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-025 | 1991 | 212.9 | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-025 | 1991 | 202.9 | NR | NR | < 0.5 | | 50 | 50 | NR |
| CP-02-025 | 1991 | 195.9 | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-032 | 1991 | 212.3 | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-032 | 1991 | 202.3 | NR | NR | < 0.5 | | 23 | 23 | NR |
| CP-02-032 | 1991 | 195.3 | NR | NR | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-033 | 1991 | N/A | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-037 | 1991 | 183.85 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-037 | 1991 | 173.85 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-037 | 1991 | 161.85 | < 0.5 | < 0.5 | < 0.5 | | < 0.5 | < 0.5 | NR |
| CP-02-039 | 1991 | 173.55 | < 0.5 | < 0.5 | 500 | | 30 | 530 | NR |

a/ feet msl = feet above mean sea level

b/ ppb = parts per billion

c/ trans-DCE = trans-dichloroethlene

d/ cis-DCE = cis-dichloroethlene

 e/ TCE = trichloroethlene

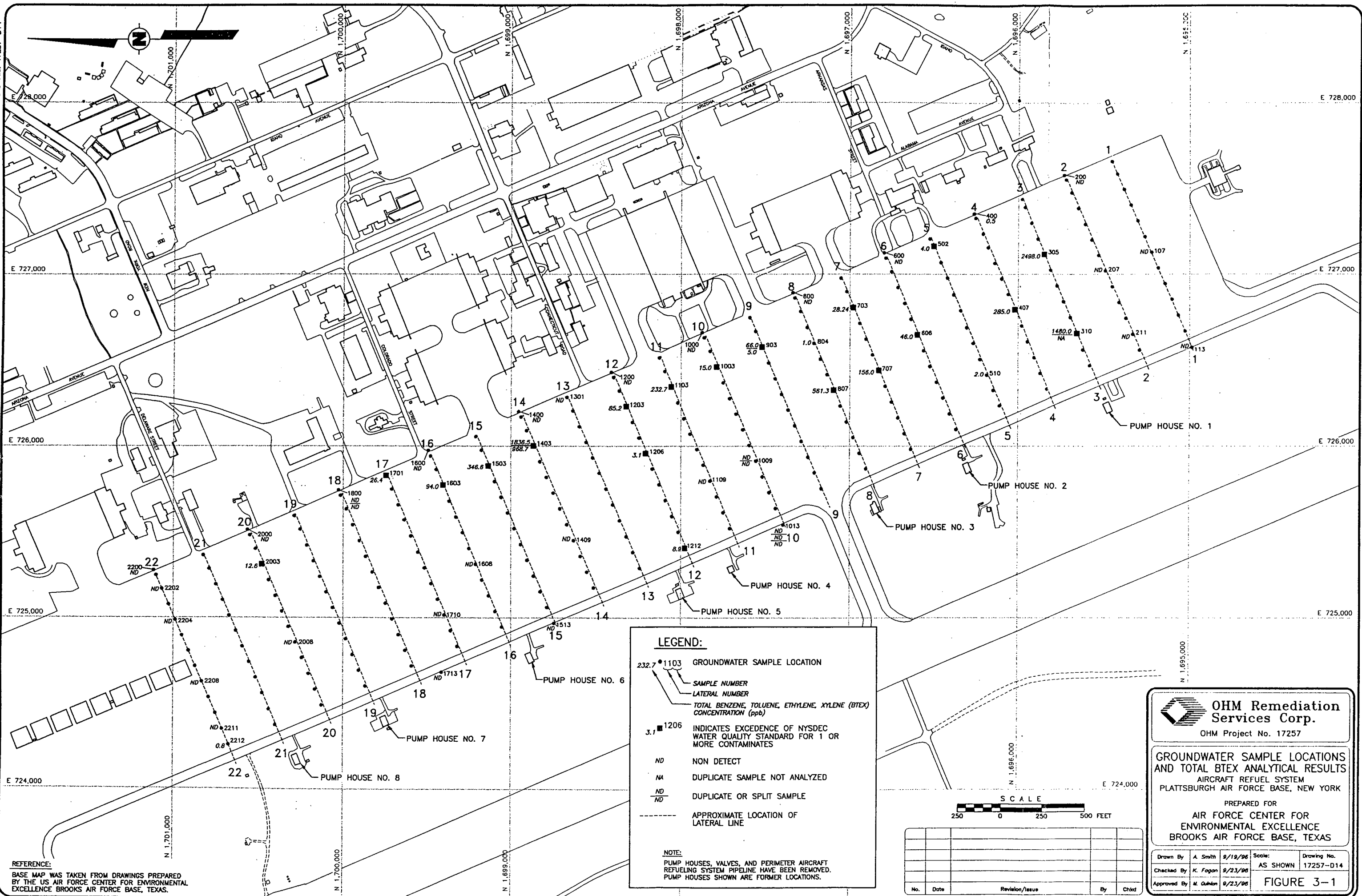f/ < 0.5 = below practical limit of quantitation

g/ NR = not reported

h/ dil = dilution factor

i/ N/A = not applicable

\* estimated feet below ground surface

Note: Background sampling locations placed in boldface

**LEGEND:**

232.7 ●1103  GROUNDWATER SAMPLE LOCATION
  SAMPLE NUMBER
  LATERAL NUMBER
  TOTAL BENZENE, TOLUENE, ETHYLENE, XYLENE (BTEX) CONCENTRATION (ppb)

3.1 ■1206  INDICATES EXCEDENCE OF NYSDEC WATER QUALITY STANDARD FOR 1 OR MORE CONTAMINATES

ND  NON DETECT

NA  DUPLICATE SAMPLE NOT ANALYZED

ND/ND  DUPLICATE OR SPLIT SAMPLE

- - - - - -  APPROXIMATE LOCATION OF LATERAL LINE

**NOTE:**
PUMP HOUSES, VALVES, AND PERIMETER AIRCRAFT REFUELING SYSTEM PIPELINE HAVE BEEN REMOVED. PUMP HOUSES SHOWN ARE FORMER LOCATIONS.

SCALE
250  0  250  500 FEET

| Drawn By | A. Smith | 9/19/96 | Scale: | Drawing No. |
|---|---|---|---|---|
| Checked By | K. Fagan | 9/23/96 | AS SHOWN | 17257-D14 |
| Approved By | M. Quinlan | 9/23/96 | | FIGURE 3-1 |

| No. | Date | Revision/Issue | By | Ckd |
|---|---|---|---|---|

REFERENCE:
BASE MAP WAS TAKEN FROM DRAWINGS PREPARED BY THE US AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE BROOKS AIR FORCE BASE, TEXAS.

CAD File: 17257-D14
Plot Scale: 1" = 260    xref = topo-2

LEGEND:

0.7 ●2211    GROUNDWATER SAMPLE LOCATION
                └─ SAMPLE NUMBER
                └─ LATERAL NUMBER
                └─ TOTAL TRICHLOROETHYLENE (TCE)
                   CONCENTRATION (ppb)

28.0 ■1109   INDICATES EXCEDENCE OF NYSDEC
             WATER QUALITY STANDARD FOR TCE

ND           NON DETECT

NA           DUPLICATE SAMPLE NOT ANALYZED

ND/ND        DUPLICATE OR SPLIT SAMPLE

- - - - -    APPROXIMATE LOCATION OF
             LATERAL LINE
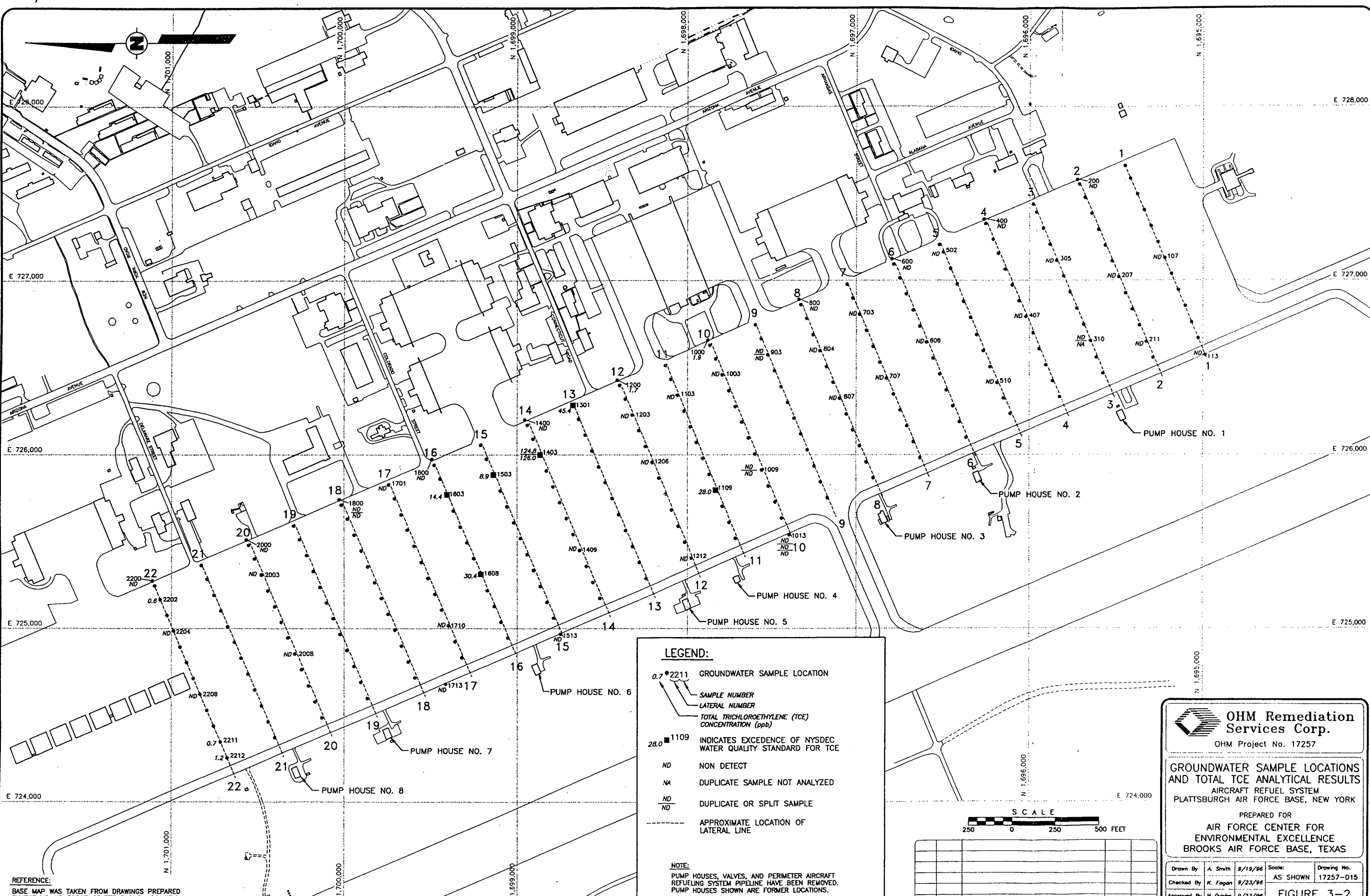
NOTE:
PUMP HOUSES, VALVES, AND PERIMETER AIRCRAFT
REFUELING SYSTEM PIPELINE HAVE BEEN REMOVED.
PUMP HOUSES SHOWN ARE FORMER LOCATIONS.

REFERENCE:
BASE MAP WAS TAKEN FROM DRAWINGS PREPARED
BY THE US AIR FORCE CENTER FOR ENVIRONMENTAL

SCALE
250    0    250    500 FEET

OHM Remediation
Services Corp.
OHM Project No. 17257

GROUNDWATER SAMPLE LOCATIONS
AND TOTAL TCE ANALYTICAL RESULTS
AIRCRAFT REFUEL SYSTEM
PLATTSBURGH AIR FORCE BASE, NEW YORK

PREPARED FOR
AIR FORCE CENTER FOR
ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE, TEXAS

| Drawn By | A. Smith | 9/19/96 | Scale: | Drawing No. |
|---|---|---|---|---|
| Checked By | K. Fagan | 9/23/96 | AS SHOWN | 17257-D15 |
| Approved By | M. Quinlan | 9/23/96 | | FIGURE 3-2 |

| No. | Date | Revision/Issue | By | Chkd |
|---|---|---|---|---|

CAD File: 17257-D15

Plot Scale: 1 = 250    xref - topo-2